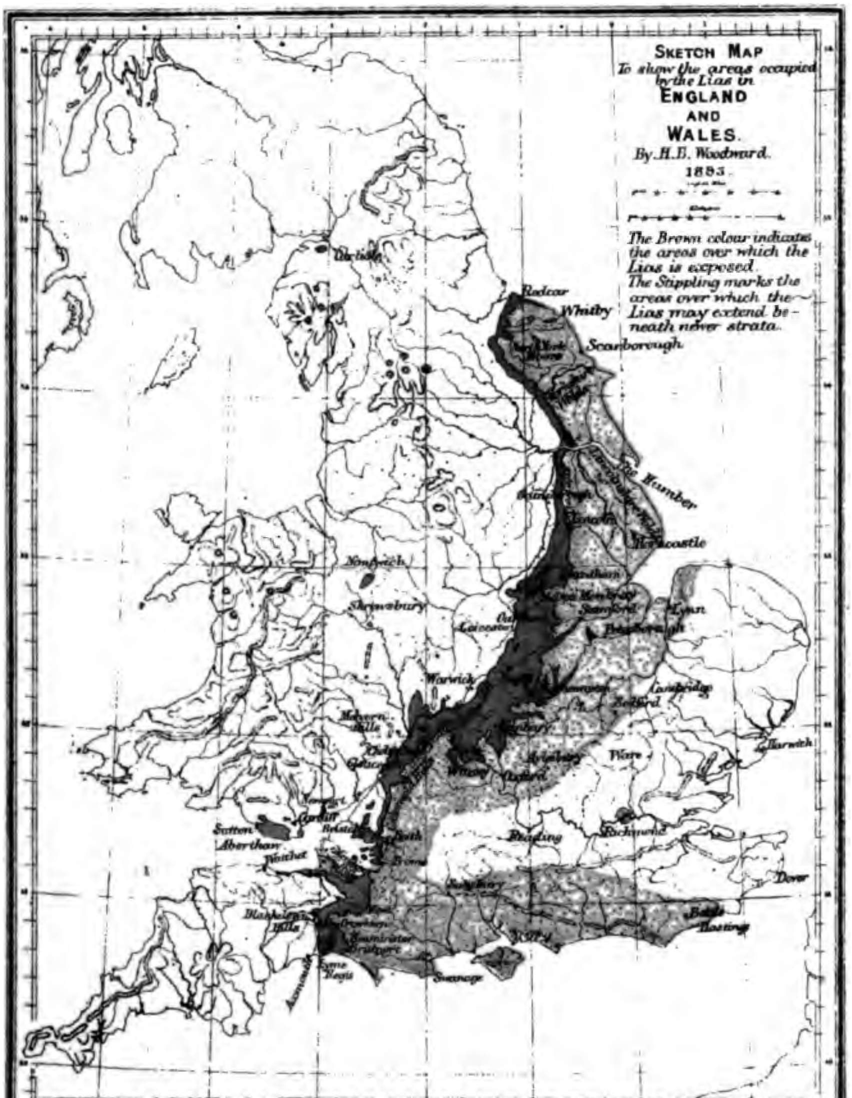
GEOLOGICAL SURVEY OF THE UNITED KINGDOM

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# MEMOIRS OF THE GEOLOGICAL SURVEY

OF THE

## UNITED KINGDOM.

THE

# JURASSIC ROCKS

OF

# BRITAIN.

## VOL. III.

## THE LIAS OF ENGLAND AND WALES (YORKSHIRE EXCEPTED).

BY

HORACE B. WOODWARD, F.G.S.

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# PREFACE.

In pursuance of the scheme for completing the Memoirs of the Geological Survey by the publication of stratigraphical monographs of the different geological formations of the British Isles, the task of describing the Jurassic system south of the Humber was entrusted to Mr. H. B. Woodward. The present volume, coming after the two by Mr. Fox-Strangways issued last year, forms the third volume of the Jurassic Monograph, and is the first instalment of Mr. Woodward's work. It is devoted to a detailed account of the Lias.

Following out the general plan adopted for these Memoirs, Mr. Woodward has endeavoured to summarise our knowledge of the different subdivisions of the Lias, with especial reference to their stratigraphical variations and their economic products. He has availed himself not only of the information gathered by the officers of the Survey, but of the voluminous Liassic literature which has been published in this country, so as to present a compendium of what is at present known regarding the subject.

In tracing the labours of those who preceded the detailed mapping of the Survey, we may note with some interest that an original sketch-survey, on the one-inch Ordnance maps, was made by William Lonsdale between 1827 and 1836 over a great part of the area described in the present volume. This early pioneer in British Geology, following the outlines first given by William Smith, and proceeding from near Bath across the Cotteswold district, made his way by a series of oblique traverses through the Midland Counties to the Humber. H. E. Strickland also mapped portions of the Lias and New Red Sandstone on the borders of Gloucestershire, Worcestershire, and Warwickshire between the years 1834 and 1837. Shortly afterwards De la Beche, in the early days of the Geological Survey, pushed his way from Cornwall and Devon into Somerset and Dorset, and before the year 1839 had begun the official mapping of the Jurassic rocks. This work was carried on by H. W. Bristow, and partly by W. T. Aveline, in Dorset, Wilts, and Somerset, and by Ramsay in Gloucestershire, followed afterwards by E. Hull, H. H. Howell, H. Bauerman, R. Trench, T. R. Polwhele, and A. H. Green, by

whom the mapping was extended into the Midland Counties. A little later J. W. Judd, in prolonging the work through Northamptonshire and Rutlandshire, introduced into it the practice of following out definite palæontological zones, without which the systematic correlation of the fossiliferous formations cannot be satisfactorily undertaken.

The northward extension of the mapping of the Jurassic formations was subsequently carried out chiefly by W. H. Holloway and W. A. E. Ussher, with the co-operation of W. H. Dalton, A. C. G. Cameron, and A. J. Jukes-Browne. The survey of these rocks north of the Humber was made mainly by C. Fox-Strangways, C. Reid, and G. Barrow.

The present volume has been prepared entirely by Mr. Woodward. His training in the field-work of the Survey had made him intimately acquainted with the Jurassic rocks, for between the years 1867 and 1874 he was engaged under Mr. Bristow, the late Director for England and Wales, in re-surveying the Secondary formations in the South-west of England and the South of Wales.

As the system of publishing sheet-memoirs in elucidation of the maps of the Survey did not come into operation until after 1856, no Memoirs have yet been issued dealing with the Secondary formations of Dorset, and of Western and Southern Somerset, excepting De la Beche's general Memoir "On the Geology of Cornwall, Devon, and West Somerset," which appeared in 1839, and his classic essay "On the Formation of the Rocks of South Wales and South-Western England," which was published in the first volume of the Memoirs of the Geological Survey in 1846. Hence for a large region in the south-west of the country, embracing many of the districts where the Jurassic rocks are typically developed, there were no official descriptions available for the preparation of a general monograph. Mr. Woodward has thus been compelled to re-visit the ground, to study the best sections, and to trace the gradual stratigraphical changes of the several formations from district to district. The following chapters will consequently be found to contain much new material. All the sections, except where otherwise stated, are original, and the author has likewise, wherever possible, verified the descriptions of other observers quoted by him. A large number of fossils have been collected by him, and these have been named by Messrs. Sharman and Newton, the Palæontologists of the Survey.

Reference will be found in the text to the sources of information made use of in the preparation of this volume. No geologist who follows in their footsteps can withhold his tribute of admiration for the labours of Strickland, Thomas Wright, Charles Moore, E. B. Tawney, and Professor R. Tate. Besides the work of these writers, assistance has been obtained from the published papers of Messrs. W. D. Carr, W. D. Crick, and E. Wilson. In the field, while working on the Liassic part of his subject, Mr. Woodward has been further personally aided by Mr. Alfred Gillett of Street, the Rev. H. H. Winwood of Bath, Mr. T. Beesley and Mr. E. A. Walford of Banbury, the Rev. P. B. Brodie of Rowington, Mr. T. J. Slatter of Evesham, Mr. R. F. Tomes of South Littleton, and Mr. Beeby Thompson of Northampton, to all of whom the thanks of the Geological Survey are due.

With regard to the illustrations in the present volume, Dr. Henry Woodward has been good enough to supply a number of engravings of fossils from the official guides to the Department of Geology in the British Museum, and other clichés have been taken from the wood-cuts of Liassic fossils in my Text-book and Class-book of Geology. The sources of the several figures are acknowledged in the List of Illustrations.

ARCH. GEIKIE,
Director-General.

Geological Survey Office,
28, Jermyn Street, S.W.
12th June 1893.

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OF

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(YORKSHIRE EXCEPTED).

## CHAPTER I.

## INTRODUCTION.

*The term Jurassic—Extent of the Jurassic Rocks in Britain—Relations of the Rocks to the Formations above and below.*

THE foundations of Geological Science are associated more closely with the Jurassic Rocks of this country, than with any other series of strata. Familiarly known as the Lias and Oolites, the main subdivisions of these rocks had been determined and their life-history to a large extent ascertained, long before the name Jurassic came to be generally applied. To the Jura mountains on the borders of France and Switzerland, where the "Jura limestone" has been known from time immemorial, we owe the name, which was introduced by Von Humboldt. As early as 1795 he employed the term "Jura limestone" in a limited geological sense, while in 1823 he used the more comprehensive names "*Jurassique*" and "*Jura formation*."* W. D. Conybeare had in 1813 recognized the identity of the Jura limestone with the Oolitic formations in England†; but not till after the publication of Oppel's great work on the "Juraformation" (1856–58), was the term Jurassic generally adopted in this country.

The Jurassic rocks come to the surface over a large tract of Britain. In England they extend from the cliffs between Axmouth and Swanage, on the coasts of Devonshire and Dorsetshire, through the Midland counties, to the cliffs and moorlands of East Yorkshire. Outlying portions of the rocks occur in West Somerset, in Glamorganshire and Monmouthshire, in Worcestershire, Shropshire, Cheshire, and also in Cumberland; while small inlying masses appear at the surface in Sussex. In the far north of

* Alex. de Humboldt, Essai géognostique sur le gisement des Roches, 1823, pp. 269, 275. (English translation, pp. 36, 359.)

† He based his correlations on the descriptions of Giovanni Arduino (1759); Rep. Brit. Assoc. for 1832, p. 388.

Scotland we find remnants of the strata along the borders of the Moray Firth, near Cromarty, and in Sutherlandshire; and again in Mull and Skye and other of the western islands and adjoining tracts of the mainland. In Ireland there are representatives of the Lower Jurassic rocks near Belfast.

The Jurassic rocks of Yorkshire form the subject of a separate section of this Memoir; those of Scotland and Ireland will likewise be described separately, so that the tracts to which attention is now directed, include (1) the main outcrop of the English Jurassic rocks from the Dorset coast to the low cliffs of Whitton, on the southern Humber shore, together with the underground extent of the strata; and (2) the outlying masses that occur in the north and west of England and in South Wales.

The main mass of the Jurassic strata thus traverses the central portions of England in a northerly and north-easterly direction. Including both Lias and Oolites, this great system is made up of many alternations of sand, clay, and limestone, with every intermediate variety of these materials; a system whose maximum thickness may be estimated at from 4,500 to 5,000 feet. Inclined gently towards the east and south-east, and having suffered considerable denudation, the harder and more porous beds outcrop in escarpments that face westwards or north-westwards, and the resultant features are a series of stonebrash hills and clay vales. Among the more prominent ridges are the Cotteswolds, that rise in places a little over 1,000 feet, Edge Hill, and "The Cliff" which supports the cathedral of Lincoln. To these physical features especial attention will be given in the sequel.

The Jurassic rocks being based on the red marls and sandstones of the Trias, the downward limit of the system was easily recognized by the early geologists; it was marked off by the "Red ground" of the vale of Taunton, the Severn valley, and the central plain of England. The upward limit of the series was by no means so clearly discerned. The dip brings on newer and newer strata in an easterly direction, and the Jurassic formations are in some places covered conformably by Cretaceous rocks. Nevertheless over considerable areas the lowest Cretaceous strata are wanting, and higher portions of that system stretch irregularly over the worn surfaces of the Jurassic rocks, concealing many of their subdivisions.

How far the Jurassic rocks extend below ground in the south and east of England is of course a matter of speculation. The highest member of the system appears at the surface in one part of Sussex, and other portions of the Oolitic series have been found at various depths in the same county, in Kent, and beneath the London area. Further references will be made to this subject.

### *Progress of knowledge concerning the Jurassic Rocks—Researches of William Smith.*

That the Jurassic Rocks of England early received a large amount of attention is not surprising. The strata furnish our

most valuable freestones, as well as many other economic products, and the numerous excavations naturally attracted notice. Moreover the strata themselves are often exceedingly rich in organic remains. These were noticed by Leland in his celebrated Itinerary (begun about 1538),* and later on they excited the curiosity of the Naturalists of the seventeenth century.

The growth of our knowledge was, however, dependent chiefly on the economic products, for the building-stones have been employed, since Roman and Saxon times, in the construction of city-walls, bridges, castles, abbeys, cathedrals, churches, and humbler edifices. Various rocks, including both Lias and Oolites were used by the Romans in their tesselated pavements.†

From these early times, in fact ever since the beds were quarried for freestone, road-stone, or lime-burning, many local names came into use, such as the Barnack Rag, Cheltenham freestone, Taynton stone, Doulting stone, Ham Hill stone, Chilmark stone, &c. As some of the beds, worked so long ago, became exhausted, or as different landholders ascertained that stone could be obtained on their grounds, so quarries were opened in other localities, and gradually a knowledge must have been acquired of the "run" or "lie" of the principal beds. The same remarks would apply to the chief deposits of tile-earth, brick-earth, and pottery clay.

While much information must thus have been gained by those engaged in the practical work of quarrying and brick-making, and by those who selected the stone for building-purposes; yet it was long before any systematic attention could be given to the subject, or the results of observations could be generally known. After the introduction of printing, and when maps had attained a fair degree of accuracy, the attention of the learned became more and more drawn to the subject. In the seventeenth century the general superficial distribution of the rocks was so manifest, that proposals were made to indicate their limits on maps, and to Dr. Martin Lister (1684) we owe the first practical suggestion for a geological survey.‡

The attention of the earlier Naturalists was devoted chiefly to the origin of the "Extraneous Fossils," "Petrifactions," or Organic Remains found in the various strata; but they were often perplexed to decide whether these "formed stones" were "naturally produced by some extraordinary plastic virtue, latent in the earth, in quarries where they are found, or whether they rather owe their form and figure to the shells of the fishes they represent."§ Many illustrations of these fossils were published in the works of Robert Plot (1677), Martin Lister (1678),

* Itinerary, Ed. by T. Hearne, vol. viii. p. 2 (Oxford, 1710–12); A. C. Ramsay, Passages in the History of Geology (part 2), 1849, p. 15.

† J. Buckman and C. H. Newmarch, Illustrations of the Remains of Roman Art, p. 49.

‡ See Phil. Trans., vol. xiv. p. 739; and Fitton, Notes on the Progress of Geology in England, reprinted from the Phil. Mag. (1832–33), 1833.

§ Plot, Natural History of Oxfordshire, p. 111. See also Phillips, Geology of Oxford, pp. 2, &c.

Edward Lhwyd (1699), the Rev. John Morton (1712), John Hill (1748), and John Walcott (1779). Lister compared the fossil with the recent species, and Dr. John Woodward (1729) clearly recognized that there are "digg'd up, out of the earth, great numbers of shells that differ not in any respect, from those that the Land, salt and fresh Water doth yield us."* The true nature of Fossils, and the general use of that term, is largely owing to the work of James Parkinson of Hoxton (1804).†

That certain strata occur in a regular order was noticed as early as 1719 by John Strachey, and he was evidently aware that above the Coal-measures in Somersetshire the following strata occurred in upward succession:—Red earth, Lyas, Freestone.‡ Other writers, like John Hill (1748), and Emanuel Mendes Da Costa (1757), gave accounts of the various rocks and of the uses to which they were put. Little progress, however, seems to have been made with regard to a knowledge of the sequence of strata for a number of years, the next important account of the rocks being given in 1760 by the Rev. John Michell, who "explains most clearly the arrangement of the strata in England."§ A manuscript Table of Strata by Michell, bearing the date 1788, was subsequently published, and therein the succession beneath the rocks now grouped as Cretaceous, was stated to comprise the "Northampton lime, and Portland lime, lying in several strata," and then the "Lyas strata." Below, the divisions of the New Red Sandstone and Coal-strata were marked. Nevertheless, as observed by Sedgwick, no part of the Woodwardian Collection at Cambridge was stratigraphically arranged by Michell, although he was Woodwardian Professor from 1762 to 1770. The significance of the sequence of rocks and fossils was not yet discerned.

It was William Smith who, after researches extending over 20 years, first carried out the undertaking to make a geological map of England and Wales. Projected about the year 1794, the work was completed before 1812, and published in 1815, the scale adopted being 5 miles to an inch. It must not be forgotten that, between 1794 and 1813, the Board of Agriculture published a number of Reports containing much local geological information; and, as Conybeare remarked, to this Board "must undoubtedly be ascribed the honour of having produced the earliest geological maps of any part of England."

When the strata came to be traced on the ground and depicted on a map, the necessity for more precise terms arose. Various freestones that had come into the market under different local names such as the Bath stone, the Minchinhampton stone, and the Taynton stone, proved to be on the same horizon, and the term Great or Bath Oolite was applied to them; so also the Cheltenham freestone, the Doulting stone, and the Ham Hill stone proved to

* An Attempt towards a Natural History of the Fossils of England. Tome I., part ii., p. 6.

† Organic Remains of a former World, vol. i. p. 34.

‡ Phil. Trans., vol. xxx. p. 968; xxxi., 395. (Papers reprinted in 1727.)

§ Phil. Trans., vol. li, p. 566; Fitton, *op. cit.*, p. 14; and J. Farey, Phil. Mag. vol. xxxvi. 1810, p. 103.

be on the same general horizon, and the term Inferior Oolite came to be applied.

To William Smith we are mainly indebted for the first clear definitions of our strata. He determined the sequence of the Jurassic rocks in the west and south-west of England, and pointed out their relations to the soils and physical features. His most important generalization was that the different strata are characterized by fossils more or less peculiar to them, thus establishing the fact that strata can be identified by their organic remains. Moreover he pointed out that many of the rocks had been in succession the bed of the sea, and that the fossils were remains of animals that had lived and died at or near the places where they are now embedded.*

Hence the prominent names of many of our rocks were taken from the south-western and western parts of England, either from terms in local use or from localities where the beds were exposed. It may be useful therefore to give the following Table showing the names successively adopted by William Smith:—†

TABLE SHOWING THE SUBDIVISIONS OF THE JURASSIC ROCKS ACCORDING TO WILLIAM SMITH.‡

| 1799. | 1812. | 1815–16. | Names now adopted. |
|---|---|---|---|
| | | Purbeck Stone | Purbeck Beds. |
| | | Portland Rock | Portland Stone. |
| | | Sand | Portland Sand. |
| | | Oaktree Clay | Kimeridge Clay. |
| | | Coral Rag and Pisolite: Sand | Corallian Beds. |
| Clay | Dark Blue Shale | Clunch Clay and Shale | Oxford Clay. |
| | | Kelloway's Stone | Kellaways Rock |
| Sand and Stone | Cornbrash | Cornbrash | Cornbrash. |
| | | Sand and Sandstone | Forest Marble. |
| Clay | Forest Marble Rock | Forest Marble | |
| Forest Marble | | Clay over Upper Oolite | Bradford Clay. |
| Freestone | Great Oolite Rock | Upper Oolite | Great Oolite. |
| Blue Clay, Yellow Clay, Fuller's Earth, Bastard ditto and Sundries. | | Fullers Earth and Rock. | Fullers Earth and Fullers Earth Rock. |
| Freestone | Under Oolite | Under Oolite | Inferior Oolite. |
| Sand | | Sand | Midford Sand. |
| | | | Upper Lias. |
| | | Marlstone | Middle Lias. |
| Marl Blue | Blue Marl | Blue Marl | Lower Lias. |
| Blue Lias | Blue Lias | Blue Lias | |
| White Lias | White Lias | White Lias | Rhætic Beds. |
| Marl stone, Indigo and Black Marls. | | | |
| Red-ground. | Red Marl and Gypsum. | Red Marl | New Red Marl, &c. |

It will be seen by reference to this Table that the chief divisions have been confirmed by later observation. The Purbeck Stone was, however, associated by Smith with the Kentish Rag, &c., while the Upper Lias was omitted, doubtless because it is very inconspicuously developed in Somersetshire. The Alum Shale (Upper Lias) of Yorkshire was grouped by him with the Oxford Clay.

* See Memoirs of William Smith, by John Phillips, p. 141; see also Fitton, *op. cit.*, pp. 29, &c.

† Memoirs of W. Smith, by John Phillips, pp. 30, 146. See also Table by Buckland (1818) in W. Phillips' Outline of the Geology of England and Wales; and Table by Sedgwick (1821) in A Syllabus of a Course of Lectures on Geology.

‡ See also Table given by C. Fox-Strangways, Jurassic Rocks of Yorkshire, vol. i. p. 20.

An excellent description of the Oolitic strata of parts of Gloucestershire, Somersetshire and Wiltshire, accompanied by plates of many of the fossils, was published in 1813 by the Rev. Joseph Townsend, vicar of Pewsey. The title of this work* unfortunately obscured its character, for the geological facts were based largely on information furnished by William Smith, and it thus contains the earliest record of his more important observations. The prominent or characteristic fossils of the Oolites, down to the Fuller's Earth Rock, were subsequently figured by William Smith in his "Strata Identified by Organic Remains," of which only four parts were published (1816–1819). In the meanwhile, Sowerby's Mineral Conchology, of which the first volume was published in 1812, gave a new impetus to the collection and study of fossils; and several enthusiastic geologists about this time entered the field, among whom may be mentioned Thomas Webster, William Buckland, W. D. Conybeare, Adam Sedgwick, followed by W. H. Fitton, H. T. De la Beche, R. I. Murchison, William Lonsdale, and John Phillips.

William Phillips had in 1818 published "A Section of Facts from the best authorities, arranged so as to form an Outline of the Geology of England and Wales" (accompanied by a Table of Strata by Buckland); and he was joined in 1822 by Conybeare in the preparation of a second edition of this celebrated work, which became the "scientific bible" of many a zealous worker.† Conybeare was mainly responsible for the Jurassic, as well as other portions of this new edition, and having adopted the grouping of William Smith for the Jurassic rocks, "their provincial names have become classic throughout Europe."‡ In those days, however, the term Oolites or Oolitic Series was employed as a general term to include both Lias and Oolites.

It is unnecessary here to give a full account of the further progress of Jurassic geology in this country; nor could justice be done to the subject without reference to the work of geologists on the Continent.§ A list of works on the Jurassic geology of Britain, will be given in the final volume of this Memoir, and particular acknowledgment will also be made, in due course, of the labours of the many geologists who have contributed to our knowledge of the Liassic and Oolitic strata of this country.

### *Subdivisions of the Jurassic rocks.*

The subdivisions of the Jurassic rocks, established by William Smith, were based mainly on his observations in Somersetshire and Wiltshire. They are stratigraphical divisions, composed sometimes of thick strata comparatively uniform in lithological character, at

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* The Character of Moses established for veracity as an Historian, recording Events from the Creation to the Deluge. 2 vols. 4to. London. 1813–1815.

† Geikie's Life of Murchison, vol. i. p. 126.

‡ Murchison, Address to Geol. Soc., 1833, Proc. Geol. Soc., vol. ii. p. 447; and Sedgwick, Address, 1830, *Ibid.*, vol. i. p. 200.

§ See also C. Fox Strangways, Jurassic Rocks of Yorkshire, vol. i. p. 7.

other times of beds varying greatly in their component materials, but yet united by some common character. Their order of superposition was clearly proved, and their organic contents were shown to be more or less distinctive. It is important to bear these facts in mind, for all "formations" or stratigraphical divisions must, as far as possible, be regulated on these principles.

The progress of knowledge has, however, shown that, when traced across the country from the south-west to the north-east, many of Smith's divisions, and especially the sandy and calcareous strata of the Oolites, exhibit marked changes in character. Hence it has been necessary to adopt distinct stratigraphical subdivisions for some of the formations in the midland and north-eastern counties. In no case can these divisions be taken as of equal or approximately equal value in point of duration or physical history: they are made essentially for convenience, and it must be remembered that all are subject, often to a considerable extent, to variation in thickness.

The Jurassic system (Juraformation) of Germany was separated into three divisions in 1837 by Leopold Von Buch; but the several stages have been somewhat differently grouped by geologists, more especially with regard to the Middle and Upper Jurassic divisions. The classification given in the Table on page 8, is that most commonly adopted.

*Sequence of rocks and Passage-beds—Planes of demarcation.*

The Jurassic rocks represent for the most part marine accumulations that were nowhere deposited in very deep water, nor at a very great distance from the old lands to whose waste the detrital materials are due. The finer and more tranquilly deposited materials, like the clays, are more persistent than the current-bedded oolitic and sandy accumlations that were deposited in shallower water.*

In certain formations, or subdivisions, only particular conditions of the sea-bed are presented to our view; with others we find evidences of the deposits of deeper and shallower water. In few cases are there preserved among Jurassic rocks the marginal accumulations that fringed the Palæozoic lands, and in no instances do we find any abysmal deposits. Estuarine characters appear in some of the beds, and these as a rule are shown in the character of the organic remains and in the more abrupt changes in the sediments: impure coal-seams are found, carbonaceous shales and sandstones become more prominently developed, variegated clays occur, and the limestones are less conspicuous. More especially do these characters prevail, at certain horizons, as we trace the beds northwards, but at the top of the series, the Purbeck beds of the south of England exhibit some entirely freshwater accumulations, as well as actual evidences of land-surfaces.

That there was a continuous sequence of deposits in the British area throughout the Jurassic period, is shown by evidence obtained

* See Hull, Quart. Journ. Geol. Soc. vol. xvi. p. 72.

TABLE SHOWING THE PRINCIPAL SUBDIVISIONS OF THE JURASSIC ROCKS FROM DORSETSHIRE TO LINCOLNSHIRE.

| — | — | South-western Counties. | Midland Counties. | Lincolnshire. |
|---|---|---|---|---|
| Lower Cretaceous. | Neocomian | Wealden Beds, &c. | | Tealby Beds.<br>Claxby Ironstone. |
| Upper Jurassic | Upper Oolitic | Purbeck Beds<br>Portland Beds<br>Kimeridge Clay | Purbeck Beds<br>Portland Beds<br>Kimeridge Clay | Spilsby Sandstone.<br>Kimeridge Clay. |
| | Middle Oolitic | Corallian Beds<br>Oxford Clay and Kellaways Rock | Ampthill Clay, &c.<br>Oxford Clay and Kellaways Rock | Corallian Clay.<br>Oxford Clay and Kellaways Rock. |
| Middle Jurassic | Lower Oolitic | Cornbrash<br>Forest Marble and Bradford Clay<br>Great Oolite and Stonesfield Slate<br>Fullonian (Fullers Earth).<br>Inferior Oolite<br>Midford Sands (passage beds) | Cornbrash<br>Forest Marble and Great Oolite Clay<br>Great Oolite Limestone<br>Upper Estuarine Series<br>Lincolnshire Limestone and Collyweston Slate<br>Lower Estuarine Series and Northampton Sands | Cornbrash<br>Great Oolite Clay<br>Great Oolite Limestone<br>Upper Estuarine Series<br>Lincolnshire Limestone<br>Lower Estuarine Series and Northampton Sands (Dogger). |
| Lower Jurassic | Liassic | Upper Lias<br>Middle Lias<br>Lower Lias | Upper Lias<br>Middle Lias<br>Lower Lias | Upper Lias<br>Middle Lias<br>Lower Lias |
| Triassic | Rhætic | Rhætic Beds | Rhætic Beds | Rhætic Beds |

in different localities; so that notwithstanding the physical changes indicated by the successive deposits of deeper and shallower water, yet some portions of the area were receiving sedimentary deposits during the period.

The evidences of transition will be pointed out in the chapters dealing with the Lias and Oolites; they are seen in Passage-beds that show the gradual passage of one formation of particular lithological character into another of dissimilar nature, or the alternation of beds at the summit of one formation with those of a type characterizing the succeeding deposit. The classification of these Passage-beds, which serve to unite formations accumulated under varying sedimentary conditions, has led to much debate of an unprofitable character. While, as Sedgwick remarked,* these evidences of conformity indicate "the perfect development of the series," yet we find abundant evidence of the more ample, or it may be said the more eventful, development of a formation at one locality than another. This may be marked by rich fossil-beds, as well as by a greater thickness of deposits, due to more rapid deposition of sediment. Hence it happens that some localities, originally chosen to designate formations, are not always the best that could have been selected; but it is obvious, that when the meaning of a term is well understood, no advantage can result from a change.

In certain localities, therefore, it is not possible to fix precise lines of demarcation between subdivisions; this is the case with the Upper Lias Clay and Midford Sands, the Great Oolite and Forest Marble, as well as other formations. Again in many localities the junctions of formations may be well-marked; as is often the case where the Lower Lias rests on the White Lias (Rhætic), the Upper Lias clay on the Marlstone, or the Fuller's Earth clay on the Inferior Oolite.

The completeness of the Jurassic record is interrupted in many instances by local erosion and by unconformable overlap; but there is no evidence of great discordance between the stratification of the unconformable strata, such as would indicate very considerable local disturbances. Nowhere in Britain do we find any evidence of contemporaneous volcanic activity; and only in Yorkshire, the north-east of Ireland, and along the western side of Scotland, are the beds affected by the subsequent intrusion of eruptive rocks.

Evidences of local erosion are shown by the presence of pebbles of previously formed Jurassic rocks. Among the current-bedded oolites the occurrence may be noted of fragments of strata formed not long previously, or of portions even of the same subdivision. Thus we find rolled pieces of oolite in some of the beds of the Inferior Oolite. Again we find rolled pieces of cement-stone or ironstone at the base of the Inferior Oolite; and in this case the pebbles have been formed from a distinct formation, the higher

* Ann. Phil 1820, vol. xxvii. p. 350.

portions of which have been subjected to local erosion. Occasionally there may be found small and more or less rolled nodules of impure and sometimes slightly phosphatic limestone, the formation of which may have been contemporaneous. (See p. 72.)

Pauses in deposition may be indicated by accumulations of different genera and species of organic remains, by phosphatic nodules and phosphatized fossils, and by burrows of Annelides and Lithodomi. The evidence of marine borers, however, cannot be taken to prove any great lapse of time. In some cases calcareous strata must have been consolidated rapidly, for we find Annelide-borings and Lithodomi in successive layers of oolite that belong to the same subdivision. Abrupt changes in the character of sedimentary accumulations may occasionally indicate a break, but such evidence cannot be relied upon. We find throughout the Jurassic series frequent alternations of clays with sandstones or limestones; changes that afford no evidence of any break in the sequence of events, but which may be attributed to variations in the currents bringing sediment. Even when such sedimentary changes are accompanied by changes in the character of the fossils, we have to consider to what extent the nature of the sea-bottom has influenced the forms of life. Marked differences in the successive assemblages of fossils, and a knowledge that elsewhere other fossiliferous strata are developed, afford (in the absence of distinct unconformity) the means by which local breaks of importance may be inferred.

In a great series of strata that exhibits considerable sedimentary changes, it is natural to find many local gaps due to paucity of sediment or to contemporaneous erosion. On account of these local unconformities and overlaps, different classifications of the strata may be made in different localities. There is evidence in some places of unconformity between the minor subdivisions of one formation such as the Lower Lias, the Inferior Oolite, or the Portland Beds. Thus there may be a break in the midst of a formation, while locally it may shade upwards and downwards into the overlying and underlying formations.

### *Lateral Changes in Formations—Stratigraphical and Palæontological Subdivisions.*

Having considered the vertical changes in the strata we may briefly allude to the lateral changes. In some cases, formations like the Inferior Oolite, the Great Oolite, and Forest Marble undergo considerable modifications as the beds are traced from place to place; so that ultimately one subdivision, like the Fullers Earth or Forest Marble, may become replaced or absorbed by another stratigraphical division. In other cases the division may taper away, not having been deposited further, or it may have been denuded.

These changes in the thickness, lithological character, and extent of the larger Jurassic divisions, are but exaggerations of what takes places in the minor divisions. A formation may be

persistent over large areas, and its subdivisions may be very inconstant. Such is the case with the Inferior Oolite and the Corallian rocks. Sections recorded in different parts of the same quarry vary, as do the records taken at different times.

The Jurassic rocks thus exhibit certain phases of the sea-bottom or of sedimentation, that endured for longer or shorter periods, the conditions changing more or less irregularly and at intervals over the area we have under consideration. The subdivisions of the rocks indicate the domination of certain physical conditions over a particular area, and we have to consider the probability of certain sedimentary conditions (or formations) enduring much longer in one area than in another. We may, for instance, have passage-beds on somewhat different horizons, for a formation, such as the Corallian, may merge upwards and downwards into the rocks above and below, gradually, and yet when traced for some distance, so irregularly that different planes of division (in point of actual age) may be taken in different localities. This is evidently the case with certain divisions of the Jurassic rocks, so that precise correlation is not possible.* To some extent palæontology comes to our aid, although for several reasons we cannot depend upon it for fixing the limits of stratigraphical subdivisions.

Each main division of the rocks has been found to yield an assemblage of organic remains more or less characteristic, some species being (so far as is known) peculiar, others especially abundant. Hence when the stratigraphical succession of the main rock-divisions has been established in one area, and their fossils have been determined, we have the means of identifying distant or isolated masses of rock by their organic remains, a fact of especial importance in reference to strata penetrated in deep borings, or thrown out of their normal position by faults or other disturbances.

The entire series of rocks being locally so intimately linked together, it is natural that the series of organic remains should also be connected; and this is really the case, for most of the genera and some of the species range through many formations, each species indeed, so far as we know, having a varied geological and geographical range. These organic remains are for convenience grouped into "zones," or assemblages characterized by a genus or species of wide-spread occurrence; but the limits of these zones are not to be rigidly defined, for as Professor Judd has remarked, "the transition from one fauna to another appears to have been in almost every instance a gradual one, the several species disappearing individually, and not in groups."†

It must be remembered that palæontological divisions are useful only when fossils are to be obtained, whereas in a large number of exposures the rocks yield few or no fossils, or perhaps none indicating a special horizon. Moreover, while we find that

* See also remarks by Prof. Judd, Geol. Rutland, pp. 50, &c.
† Geol. Rutland, p. 57.

certain kinds of rock are characterized by forms of life suited to the sedimentary conditions they represent, yet the range of some species and the incoming of new ones may be quite independent of sedimentary changes. In short, the palæontological changes frequently do not coincide with the lithological changes.

The difficulties in classification and correlation therefore appear great, but they are only so because it is sought to make divisions where none exist in Nature. Neither by lithological characters nor by fossils can we fix persistent planes of demarcation in a conformable series of strata, but both are of service in helping to fix and correlate those artificial divisions which it is necessary to adopt for the purpose of tabulating our knowledge.

It is important to determine the physical structure of each district; to represent on maps the superficial area occupied by each group of rocks, and to show their relation to the form of the ground. Hence the subdivisions of each geological system must be mainly stratigraphical; such divisions are permanent in the area to which they refer, although distinct divisions may be necessary in the same system in other areas. Purely palæontological divisions must always be more or less vague and indefinite so far as their limitations are concerned, but the artificial division of the strata into zones irrespective of the main rock-divisions is of essential service in correlating the strata of different areas. To these zones further reference will be made.

The position of a barren group of rocks can be usually ascertained by working out its relations to beds above and below, in which beds some distinctive fossils may be obtained; or the strata themselves may in themselves present a sequence of rocks of distinctive character, such as would determine their correlation with other formations, exhibiting a similar repetition. The sands of the Middle Lias and the Midford Sands cannot always be distinguished, nor the Lower and Upper Lias clays, nor certain beds in the Inferior Oolite and Great Oolite. Many other illustrations might be given; but when we work out the stratigraphical relations and find a sequence of Marlstone, Upper Lias clay, and Midford Sands; or of Fullers Earth, Great Oolite and Forest Marble, the position of the doubtful strata can be determined.

*Sections of the Strata.*

In many instances the published records of early date furnish our only information of the strata of certain localities. In future times this is likely to be more and more the case, for the number of open sections every year decreases. This is a fact although a melancholy one for geologists. Railways have indirectly been the cause. It arises partly on account of the introduction of hard road-metal to districts and villages which in former years depended entirely on such local stone as was to be found. The "Mendip granite" (as the Carboniferous Limestone is commercially miscalled), the Hartshill stone, the Charnwood Forest and Mount Sorrel rocks, and the Clee Hill Dhu stone, are responsible for the

closing of many quarries in Jurassic areas. In places too, the slag from iron-furnaces is employed as road-metal. Again, at the larger brickyards like those near Peterborough, where machinery is extensively used, bricks of better quality and cheaper in price, can be made than is the case at many a small out-of-the-way brickyard. Consequently many of the latter have been abandoned, and more are likely to be. Moreover, owing to social changes, comparatively little building is carried on in the villages, compared with what took place in times gone by.

There are notes of many open sections, mentioned in John Woodward's "Natural History of the Fossils of England," and in old topographical works, that show their abundance in regions where sections would now be a boon; but it is probably only within the last 30 years, and particularly within the last 15 years, that so many pits and quarries have been closed.

The railways themselves have given some compensation in the numerous cuttings, but the majority of these are soon obscured. Deep borings have added to and are continually increasing our knowledge, but they do not afford those happy hunting grounds for fossils, which many a stone-quarry and brickyard have furnished. It must be remembered, however, that many localities regarded as very fossiliferous, owe their celebrity to the energy of local collectors.

*Fauna and Flora.*

The organic remains, studied in connexion with the sedimentary characters of the rocks, give a clue to the physical conditions that characterized the successive periods.

The fauna and flora of the Jurassic system is, on the whole, rich and varied, especially when contrasted with the preceding and comparatively barren New Red Rocks; and a study of the Lias and Oolites takes us to some of the most famous localities for fossils. The west of England appears to be the district most favoured by collectors, and places such as Lyme Regis, Weymouth and Swanage, Yeovil, Chippenham, Stonesfield and Cheltenham, have attained a greater fame than other fossiliferous regions further north in the area to which attention is now directed.

A general consideration of the fauna bears striking testimony to the imperfection of the Geological Record, especially as regards the preservation of terrestial forms of life. Mammals, of which the earliest traces in the shape of *Microlestes*, are recorded from the Rhætic Beds, have been detected in the Jurassic series in the Stonesfield Slate and in the Purbeck Beds. These include Marsupials and Insectivores. Cetacean vertebræ have been doubtfully recorded from the Kimeridge Clay.

No traces of Birds have been found in any of the Jurassic Rocks of this country * The Dinosaurian Reptiles, of which the

* Abroad, the *Archæopteryx* of Solenhofen and the *Laopteryx* (?) of Wyoming, occur in Upper Jurassic Strata.

*Cetiosaurus* and *Iguanodon* are examples, are considered to have been dwellers on the land; and in the Purbeck Beds we find *Macellodus*, the earliest Jurassic representative of the Lizards.

Insects of all kinds have been found plentifully at certain horizons, in the Lower and Upper Lias, in the Stonesfield Slate, and in the Purbeck Beds.

Land and Freshwater Mollusca occur in some divisions of the Oolites, and more especially in the Purbeck Beds; their occurrence in the Lias, according to Mr. E. Wilson, requires confirmation.

Remains of land organisms are thus but scantily preserved, and the vertebrate remains are extremely rare even in those estuarine or fresh-water accumulations where we might expect to find them more commonly. There is, however, ground for hoping that they may be found eventually at localities and horizons other than those in which their remains have at present been discovered. Indeed, since these remarks were written, the first British Cretaceous Mammal has been discovered, in the Wadhurst Clay, near Hastings.*

Insects, occurring as they sometimes do in purely marine deposits, were probably in such cases blown out to sea, or floated into the sea by rivers. Drift-wood and lignite occur at various horizons. Among the plant-remains, those of Cycads and Conifers are the more abundant forms. Ferns are not often preserved: many species originally described as ferns are now known to be Cycads. Dr. J. H. Balfour speaks of the Jurassic period as the reign of Gymnosperms. The first definite traces of *Cycadeæ* are recorded; none of the forms obtained are very large, but the *Coniferæ* present arborescent types of the first magnitude.† Monocotyledons are occasionally preserved.

Of the marine or partially marine forms of life many Reptiles, and especially the *Ichthyosaurus* and *Plesiosaurus* are characteristic (see Figs. 2–6, pp. 37–39). Recent researches tend to show that the former genus had a more extended caudal fin than is usually represented in figures.‡ Other Reptiles, more or less aquatic in their habits, are the Pterodactyls *Dimorphodon* and *Rhamphocephalus*; the Crocodilians *Teleosaurus*, *Dacosaurus*, and *Steneosaurus*; and the Chelonia. No Snakes are known. The larger Saurians are more abundantly preserved in the Lias limestones and clays, and in the Oxford and Kimeridge Clays.

The Fishes are well represented and include the Selachians, *Hybodus*, *Acrodus*, *Strophodus*, *Asteracanthus*, and *Squaloraja*; and Ganoids, such as *Dapedius*, *Pholidophorus*, *Leptolepis*, *Lepidotus*, and *Mesodon* (*Pycnodus*). (See Figs. 8–11, pp. 40, 41.) They occur in various strata, but more especially in the limestones, including the oolitic beds, and in the shales.

Of Mollusca we find the first traces in this country of *Ammonites* and *Belemnites*. They occur more or less abundantly

* A. S. Woodward, Proc. Zool. Soc., 1891, p. 585.
† Count de Saporta, Geol. Mag., 1872, p. 274.
‡ Lydekker, Natural Science, 1892, p. 514.

in the clays and earthy limestones, and in the sandy strata, but rarely in the false-bedded oolitic rocks. The Nautilus is also found.

The Gasteropods and Lamellibranchs comprise mostly genera now living. The Gasteropods include *Natica, Pleurotomaria, Trochus, Turbo, Chemnitzia, Cerithium, Nerita, Actæonina, Littorina, Turritella, Patella,* and the extinct *Alaria, Bourguetia, Amberleya* and *Nerinæa:* they are most abundant in the limestones.

The Lamellibranchs include *Arca, Astarte, Avicula, Ceromya, Cypricardia, Exogyra, Gervillia, Goniomya, Gresslya; Gryphæa, Hinnites, Inoceramus, Lima, Modiola, Monotis, Myacites, Ostrea, Pecten, Perna, Pholadomya, Thracia, Trigonia,* and *Unicardium.*

In several instance the colour-markings of Mollusca and Brachiopoda have been preserved. This has been noticed in species of *Natica, Nerita, Cyprina, Hinnites, Pecten, Terebratula,* and *Waldheimia.** The occurrence has been noted of a "pearl-like body" on a specimen of *Gryphæa,* derived probably from the Oxford Clay, but found in the Glacial Drift of Muswell Hill, Hornsey.†

Species of *Ostrea* and *Gryphæa* often constitute conspicuous bands and sometimes thick beds. Thus in the Lower Lias the basement-beds are frequently crowded with specimens of *Ostrea liassica,* and at a higher horizon on the Glamorganshire coast, and especially at Fretherne in Gloucestershire, there are bands crowded with *Gryphæa arcuata.* It is interesting to note that similar bands occur as far north as Raasay and Broadford in Skye. In the Inferior Oolite of the neighbourhood of Cheltenham and Stroud, there is the Gryphite Grit, largely made up of specimens of *Gryphæa sublobata.* Varieties of *Ostrea acuminata* and *O. Sowerbyi* form a thick band in the Fullers Earth near Weymouth. *O. Sowerbyi* is abundant in the Forest Marble, and *O. subrugulosa* in the Great Oolite clays. *Gryphæa bilobata* is characteristic of the Kellaways Rock, and large forms of *Gryphæa dilatata* are prevalent at the top of the Oxford Clay. *Ostrea deltoidea* forms bands in the iron-ore of Westbury in Wiltshire at the top of the Corallian rocks, and also at the base of the Kimeridge Clay. In the Lower Portland Beds at Swindon there is a marked layer largely made up of *Exogyra bruntrutana,* and in the Purbeck Beds of Dorsetshire and Wiltshire there is the remarkable Cinder Bed, formed mainly of *Ostrea distorta.*

Some of the species of Lamellibranchs have a wide range: among these may be mentioned, *Lima duplicata, L. pectiniformis, Avicula inæquivalvis, Pecten demissus, P. lens,* &c.

Brachiopoda are exceedingly abundant in the calcareous strata, and like the oysters there are species that occur gregariously, and

* Lycett, Ann. Nat. Hist., 1850, p. 423; J. F. Blake, Quart. Journ. Geol. Soc., vol. xxxvi., p. 201; G. F. Whidborne, *Ibid.*, vol. xxxix., p. 499; E. Wilson, Geol. Mag., 1891, p. 458.

† Morris, Ann. Nat. Hist., ser. 2, vol. viii., plate 4, fig. 16.

characterize different horizons. Some Palæozoic forms like *Spiriferina* and *Leptæna* have lingered on to Liassic times, while some new genera like *Thecidium* make their appearance. Most abundant are species of *Rhynchonella*, *Terebratula*, and *Waldheimia*. Polyzoa are found abundantly in some of the calcareous strata.

Crustacea are well represented, although the larger forms are not particularly abundant. The chief groups had appeared previous to Jurassic times. The Macroura include *Eryon* and *Glyphea*. Isopods are occasionally preserved, while Ostracods have been found in abundance at certain horizons.

Of the Insects, though the remains that have been obtained indicate a great number and variety of forms, they are mostly fragmentary, consisting of wings and elytra. Annelides, represented by *Serpula*, *Ditrupa*, and other genera are not uncommon.

Echinodermata are plentifully preserved in the limestones, and more especially in the oolitic beds. The Crinoids include *Pentacrinus*, *Extracrinus*, and *Apiocrinus*. The Star-fishes are represented by *Ophioderma*, found in calcareo-arenaceous strata. The Echinoids include *Acrosalenia*, *Cidaris*, *Hemicidaris*, *Echinobrissus*, *Clypeus*, and many other genera.

Corals are plentiful at particular horizons, in the calcareous strata. In the Lias they occur abundantly at but few localities. In the Oolites we find occasional Coral-banks of somewhat limited extent, but little or no evidence of particular reefs. The more abundant genera include *Eunomia*, *Isastræa*, *Montlivaltia*, *Stylina*, *Thamnastræa*, and *Thecosmilia*.

Hydrozoa are represented by a form allied to *Solenopora*. Sponges are rare; a few marine and one freshwater species have been recorded. Numerous Foraminifera have been obtained, mostly from particular beds and localities.

### *Preservation of Fossils.*

While organic remains are as a rule more varied and abundant in the limestones, the fossils are not always so well preserved as in the clays. In the limestones the shells of the Mollusca, and frequently the Corals, may be replaced by structureless calcite. Occasionally as in the Portland "Roach," the shells have been entirely removed, and we have moulds and interior casts remaining.

In the clays the fossils are usually well preserved, and sometimes when the outer layers of Molluscan shells have disappeared they exhibit their inner nacreous layers. Such iridescent fossils are to been seen in theLias of Watchet and other places, and in the Kimeridge Clay of Brill and Market Rasen.

In the sandy strata we find comparatively few fossils; and as noticed by Mr. Clement Reid,* loamy sands appear to be very poor preservers of fossils. This is notably the case with the micaceous sandy loams of the Middle Lias. The fossils in many cases

* Pliocene Deposits of Britain, p. 132.

have been destroyed by the influence of carbonated waters, whose action may be greater when the percolation is slow. Belemnites, Pectens, and Oysters frequently remain when other calcareous organisms have perished; but the shells of these fossils are formed of calcite, and, as pointed out by Dr. Sorby,* they are more stable than shells formed of aragonite. Limestones formed of broken or comminuted shells, such as the Ham Hill Stone (Inferior Oolite) and the Forest Marble, consist largely of fragments of *Pecten* and *Ostrea*.

In many brickyards the fossils are most abundant in the deeper part of the working, and sometimes they appear only in such situations. This is irrespective of any special horizons, and is no doubt due to the fact that specimens from the higher exposed strata have been obliterated by meteoric agencies. This loss is sometimes occasioned by the decomposition of iron-pyrites and the formation of selenite from the calcareous matter of the fossils.† Belemnites, however, are more frequently preserved near the surface than some other forms. In pyritic clays the shells of Ammonites and other fossils are sometimes entirely replaced by pyrites.

Many of the fossils found in clays are much compressed, and uncrushed forms must be sought in the septaria and other nodules that may occur in the formation. The varying thickness of clay-beds in some localities may be due to unequal compression of the strata.

### *Characteristic Fossils—Fossil-beds—Zones.*

The fossil contents of each formation vary as might be expected in different localities, even on the same approximate horizon. Fossils are more or less sporadic in their mode of occurrence. Beds are comparatively barren, or rich in fossils within short distances. In one area Cephalopoda prevail, in another Lamellibranchs, in a third Brachiopoda, in a fourth Corals, and so on. On this account it is impossible to give lists of the characteristic and abundant fossils of any formation that are of more than general value; some species being common in one or more areas and rare in others. This is the case with the species of *Cardinia* and *Hippopodium* in the Lias, with the Ammonites and Brachiopods of the Inferior Oolite, &c., and it is natural, especially with gregarious forms or those dependent on certain conditions of sea-bed, &c. Thus we find many fossil-beds at various horizons; some characterised by one species, others by two or more species of the same genus, or by several genera.

It appears best to designate these beds by the generic as well as the specific name of the prominent fossil, although this plan has not always been adopted. In the Inferior Oolite certain species are prevalent at various horizons, such as *Clypeus Plotii*, *Tere-*

* Address to Geol. Soc., 1879; V. Cornish and P. F. Kendall, Geol. Mag., 1888, p. 66.

† See Duncan, Quart. Journ. Geol. Soc., vol. xxii. p. 12.

*bratula globata*, *T. fimbria*, and *Rhynchonella cynocephala*. These beds have been variously named the "Clypeus grit," the "Globata bed," the "Fimbria stage," and the "Cynocephala stage." These fossil-beds, although local, often occur at definite stratigraphical horizons. In other instances we have Saurian, Fish, and Insect Beds; beds which may be expected to occur on various horizons.

It is noteworthy that where formations attain a great thickness, they are less fossiliferous than where they are thin. Such is the case with certain beds in the Lower Lias near Radstock when compared with the equivalent beds elsewhere, and with the Inferior Oolite of Dorset when compared with the thick series near Cheltenham. Such variations indicate a paucity of sediment in certain areas. Similar results are met with in certain fossil-beds that occur at the base of formations, when some lapse of time no doubt occurred without any particular addition of sediment. The Bradford Clay fossil-bed, and the "Transition Bed" on top of the Middle Lias may be cited as instances. In such situations derived and phosphatised fossils sometimes occur; and at other times the leading fossils of a formation may be found locally in fossil-beds, as is the case in the Inferior Oolite of Dorsetshire.

The general succession in the life-forms as we ascend the geological scale is manifest, and it is convenient to separate successive assemblages of fossils under the name of "Zones."

It is found that while many species are restricted according to the nature of the sea-bed, others have an extended range, occurring far and wide over the marine area within which the European Jurassic strata were deposited. The extent of this area probably varied from time to time during the Jurassic period, but during some portions of it there was connexion with strata now found in North Africa, Madagascar, India, Australia, North and South America, and the Polar Regions. The full consideration of these matters must however be postponed for the final volume. It may, however, be mentioned that some common European Jurassic species, or closely allied forms, have been found in all the areas above mentioned.

The significant fact is that many specific forms occur over wide areas, and in the same relative order of succession, thus indicating the "practical synchronism" of the deposits in which they are entombed. Allowance must of course be made for time occupied in migration, but the results of modern research tend to show that the accumulations formed during such intervals, are small compared with the deposits that were contemporaneous.

Among the forms that extend over wide areas in Jurassic times, species of Ammonites are the most important, and next to them may be ranked the Brachiopods, some of the species of which appear to have freely migrated without reference to sedimentary conditions. Belemnites also are of importance, but the species are difficult to distinguish.

Zones may thus be defined as palæontological horizons. They are assemblages of fossils that occur in a more or less definite sequence, and mark stages in the life-history of the rocks. They

are, in the case of the Jurassic rocks, usually distinguished by the name of a prominent fossil, and Ammonites where possible are selected as indices, because their vertical range is usually more restricted than that of other characteristic fossils, different species are found in succession, and many of them occur over wide areas. Thus we have the zone of *Ammonites Bucklandi* in the Lower Lias; the zone of *A. Parkinsoni* in the Inferior Oolite, &c.

In this definition of a zone it must be borne in mind that no one of the species enumerated as belonging to the assemblage, may be confined within the limits assigned to the zone. Even the index-species may range, though less commonly above and below it, and may be absent locally from the zone it is taken to represent. Thus while a zone is a zoological division, and signifies, as Professor Tate has remarked,* rather an assemblage of species than the range of an Ammonite; yet the assemblage will be found to vary in different areas, as many of the forms that occur will have been restricted by the sedimentary conditions.

The identification of a zone must primarily depend upon the occurrence of the index-species, and of wide-spread forms that may accompany it, or of slightly different but representative species. The stratigraphical sequence of the assemblages found in different areas is again of the greatest importance in identifying zones and in determining correlation. The rocks too in places are barren of organic remains, so that the absence of zonal species and their accompaniments affords no necessary proof of unconformity. In cases where the index-species is rare or unknown, other species have locally been taken to mark zones, but on general grounds this course is not to be recommended.

It is important to distinguish between fossil-beds that contain a marked abundance of one or more species, and zones; for zones may include one or more fossil-beds, such as those to which attention has previously been drawn.

As noted in the account of the Lias, observations made on a large exposed surface of a formation show the variable character of the fossils preserved, whereas in a cliff or cutting we can seldom explore any great superficial extent of strata; our observations are usually confined within a few inches, or at most a few feet. Thus one observer may find a species only within certain limits, whereas another may obtain evidence to fix the range quite differently. Many fossils are thus preserved at different horizons, and while in one place species may have a restricted vertical range, elsewhere the range may be much greater. In most cases the limits assigned to species are based on negative evidence, and subdivisions based on the ascertained local range of any particular species may have but little value. Zones therefore are not always to be identified from the occurrence of any one specimen,

* Quart. Journ. Geol. Soc., vol. xxiii. p. 300. See also Duncan, Supp. to Brit. Foss. Corals, Part iv., No. 1, pp. 2 to 4; Judd. Geol. Rutland, pp. 48, &c., Quart. Journ. Geol. Soc., vol. xxxiv. p. 704; and H. B. W., Proc. Geol. Assoc., vol. xii. p. 295.

though a single characteristic species may furnish a reliable clue to the general horizon.

Where precise divisional planes are taken between zones, it is where some more or less marked lithological change takes place; but such divisions have at most but a local value. Where different zones occur in a series of clays that present no prominent lithological distinction, as is the case with the zones belonging to the Lower and Middle Lias Clays, the Upper Lias, the Oxford and Kimeridge Clays, only approximate boundary-lines can be affixed. Nevertheless the sequence of different assemblages can be followed better in the great deposits of clay and in the limestones of more or less detrital and sedimentary origin, than in the false-bedded oolites and sandy strata where the beds are impersistent and the fossils less frequently and less perfectly preserved.

It will be generally admitted that zones, occurring as they do irrespective of sedimentary conditions, and comprising a number of species with varying geographical and geological ranges, have no exact limitations; and thus the requirements of the geologist cannot always be reconciled with the demands of those who would subdivide our strata purely on palæontological evidence.

The great value of zones is in marking the sequence of organic remains, and in furnishing material for correlating, in a broad way, strata that are far apart. Moreover these palæontological divisions furnish convenient horizons for those engaged in working out the biological history of species.

Comparisons between the British Jurassic strata and those met with on the Continent and elsewhere will be left for the final volume.* It will be found that distinct stratigraphical divisions must be made in different areas, while the main palæontological horizons will be found to correspond in a remarkable degree over wide areas. Among the numerous zones it has been sought to establish, many have but a local importance, losing their individuality among the strata over more extended tracts. Such minor zones or "sub-zones" are sometimes useful, but there is practically no end to the number that might be made.

* See Table by C. Fox-Strangways, Jurassic Rocks of Yorkshire, vol. i. p. 21.

# CHAPTER II.

## THE LIAS.

### General Account of the Strata.

The term "Lyas" was employed in a geological sense as early as 1719 by John Strachey, who then gave a brief account of the strata above the Coal-measures in Somersetshire.* Indeed, it has been thought that the name Lyas or (as we now spell it) Lias, originated as the name of the Somersetshire quarrymen for the argillaceous limestone-beds that form the lower part of the Liassic formation ;† beds that during many centuries have been quarried for building-stone and lime-burning. It is quite possible the word is a corruption of layers or liers, and it is noteworthy that the term "Lias" is in use by quarrymen for somewhat similar bands of limestone that occur in Purbeck Beds, Great Oolite and other formations. It has however been suggested that the name may be of Norman extraction, and derived from the French *Liais*.‡

William Smith in 1799 grouped the strata as follows :—§

| | | |
|---|---|---|
| Blue Marl | = | Upper (in part), Middle, and Lower Lias clays. |
| Blue Lias | = | Lower Lias limestones. |
| White Lias | = | Rhætic Beds (top part). |

He took his classification from the country near Bath, where the Marlstone is not prominently developed, and at first some confusion arose in the grouping of that division with respect to the Upper Lias, a confusion that existed when Conybeare in 1822 arranged the strata in the following order :—||

| | | | |
|---|---|---|---|
| Upper marles | = | Upper (in part), Middle, and Lower Lias clays. | |
| Stony or true lias beds | = | Blue Lias - | Lower Lias limestones. |
| | | White Lias | Rhætic Beds. |
| Lower marles - | - | Black Shales | |
| | | Grey Marls | |

To John Phillips we owe our present grouping of the strata into Upper, Middle and Lower Lias; divisions which he established in 1829 from a study of the Yorkshire Lias, and which have been found applicable to other portions of the country.¶ Hence the strata have come to be grouped as follows :—

| | |
|---|---|
| Upper Lias - | Chiefly Clay. |
| Middle Lias - | Marlstone and Ironstone (Rock Bed). |
| | Micaceous sands and clays. |
| Lower Lias - | Clays. |
| | Limestones and clays. |

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* Phil. Trans., vol. xxx. p. 968.

† De la Beche, Report on the Geology of Cornwall, &c., p. 41.

‡ Applied to a hard freestone (Bret. *leach*, a stone; Gael. *leac*, flat stone).

§ Memoirs of W. Smith, by J. Phillips, p. 146.

|| Conybeare and W. Phillips, Outlines of the Geology of England and Wales, p. 261.

¶ Geology of Yorkshire, Part I.

We have thus a great group of strata that lie above the White Lias and its equivalents (belonging to the Rhætic Beds), and below the oolitic limestones and associated strata of the Inferior Oolite Series. In mass it is an argillaceous series, consisting of bluish-grey shales, clays, and marls, with layers of argillaceous limestone and nodular masses of limestone (cement-stones and septaria), with thick beds of sand and calcareous sandstone, ferruginous earthy and sometimes oolitic ironstone and limestone (marlstone).

The Lias attains a thickness of about 900 feet in Dorsetshire, decreasing to about 280 feet at Bath, and becoming more attenuated under Oxford. It expands again to 1,360 feet in North Gloucestershire, 760 feet at Northampton, 800 feet in Rutland, and about 950 feet in parts of Lincolnshire. In Gloucestershire we find a complete and unbroken series, and, with the exception perhaps of the Upper Lias, the same is the case in Dorsetshire; but in parts of other counties the sequence is to some extent interrupted, there being symptoms of a break between the Upper Lias Clay and overlying Oolitic strata.

On the whole the general characters of the beds are fairly persistent, although in places where the Lias fringes the Palæozoic rocks, some striking modifications are met with, and the strata become much attenuated. The rock-beds of the Middle Lias are the most variable in the series.

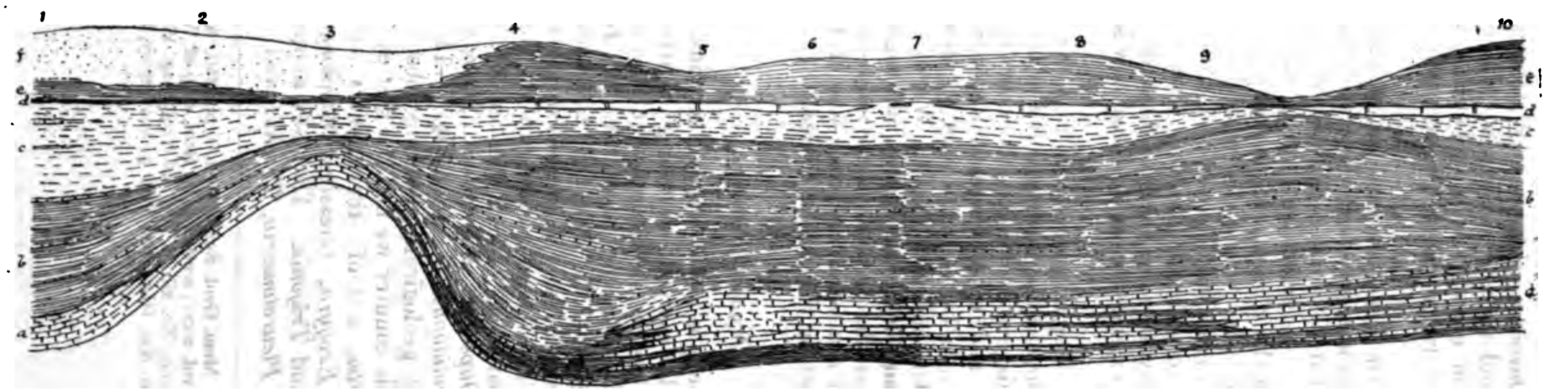
The relations of the Lias to the Rhætic Beds below and to the Inferior Oolite Series above will be discussed further on. It may however be stated that the Lias and Rhætic strata are usually conformable, and over large areas the Lias and Inferior Oolite exhibit evidence of such gradual passage that no hard line of division can be fixed, and consequently opinions vary on the question of grouping particular layers. These passage-beds between the Lias and Inferior Oolite, known as Midford Sands, form a convenient stratigraphical division that is of local importance; but it may be freely admitted that from a palæontological point of view these Sands include portions of both Upper Lias and Inferior Oolite, the equivalents of which elsewhere may more definitely be separated.

The general character of the changes met with in the Liassic formation are shown in the accompanying diagram. The vertical scale being so much in excess of the horizontal, an unnatural appearance of disturbance is produced in the vicinity of Bath where the beds are much reduced in thickness. The object of the diagram is to picture the main changes that the strata undergo; and it will be seen that the irregular development of the Lower Lias limestones, and the persistent nature of the junction between Middle and Upper Lias, are the more striking features. (See Fig. 1.)

With regard to the former extent of the Lias, we have evidence of the margin of the old sea at certain points on the M ndips and in Glamorganshire, but it is probable that these land-areas were only islets. We know not how far the Lias extended over

FIG. 1.

*Diagrammatic Section to show the chief variations in the Liassic Strata from Dorsetshire to Yorkshire.*




*f*. Midford Sands (Passage-beds).
*e*. Upper Lias clays.
*d*. Marlstone (Middle Lias " Rock-bed ").

*c*. Middle Lias sands and clays.
*b*. Lower Lias clays.
*a*. Lower Lias limestones..

1. Dorsetshire cliffs.
2. Glastonbury.
3. Bath.
4. Gloucestershire.
5. Banbury.
6. Rugby.
7. Leicester.
8. Grantham.
9. Lincoln.
10. Yorkshire.

what is now Devon and Cornwall. In West Somerset, where the Lias approaches the Devonian rocks near Watchet and Porlock, it does not present conglomeratic conditions. Its relations with the old rocks where in contact, suggest faulting, and that the Quantock and Foreland ranges formed no part of the land-area in Liassic times.*

In Monmouthshire the Lias presents its ordinary characters, dipping away somewhat abruptly from the present margin of Old Red Sandstone: so that formerly it may have stretched much further west. We have no indication there of marginal deposits. The Severn valley and the plain stretching towards Chester must have been covered by Lias continuous with that of the rest of England. Referring to the Jurassic rocks of Cumberland, both Mr. J. G. Goodchild and Mr. J. E. Marr have remarked that there is no reason why these and newer Mesozoic rocks should not at one time have extended over the area now known as the Lake District.†

In the south-east of England we know that the Lias does not extend beneath London, nor has it been found in any deep borings between the metropolis and Harwich. It occurs beneath Peterborough and Oxford, and must terminate underground towards the south-east, somewhere between the sites of those cities and Harwich, Ware, London and Richmond. We can form no idea of its extent under Hampshire and Sussex, although the evidence at our command suggests that in parts of the south-east of England the Lias is banked up against an old coast-line of the Palæozoic rocks, and is overlapped by the Oolitic Series.

## *Organic Remains.*

The Lias as a whole is rich in organic remains, and these for the most part are well preserved. The large Saurians dominated, and hence the period has been designated the Age of Reptiles or Saurozoic Epoch. Chief among these are the *Ichthyosaurus*, *Plesiosaurus* (see Figs. 2–7, p. 37), and *Dimorphodon* (Pterodactyl). Some tiny examples of *Ichthyosaurus* have been found within the pelvis of parent forms, leading to the conclusion that the animal was viviparous.‡ The Fishes include many genera, such as *Acrodus*, *Dapedius*, *Eugnathus*, *Hybodus*, *Leptolepis*, *Pachycormus*, and *Pholidophorus*. (See Figs. 8–11, pp. 40, 41.)

Most abundant, and geologically speaking most important, are the Mollusca. In this country we find the first evidence of *Ammonites* and *Belemnites*, and of other genera such as *Alaria*, *Amberleya*, *Nerita*, *Exogyra*, *Gresslya*, *Goniomya*, *Homomya*, *Hippopodium*, *Opis*, and *Trigonia*. The more abundant Gasteropods are *Cerithium*, *Pleurotomaria*, *Trochus*, and *Turbo*. Car-

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* See also De la Beche, Mem. Geol. Survey, vol. i. pp. 250, &c.; and Ussher, Proc. Somerset Arch. Soc., vol. xxxv. section 4, on Geol. map of West Somerset.

† Trans. Cumberland Assoc., No. xiii. p. 95; and Geol. Mag. 1889, p. 154.

‡ J. Chaning Pearce, Ann. Nat. Hist., vol. xvii. p. 44; Seeley, Rep. Brit. Assoc. for 1880, p. 69.

*dinia*, found also in the Rhætic Beds, is especially characteristic of the Lias.* Many of the Mollusca date from the Trias and some from earlier periods: there are few genera of Gasteropods or Lamellibranchs peculiar to the Lias, but among the former, *Cryptænia* may be mentioned.

Brachiopoda are abundant; we find the last representatives of the Palæozoic forms of *Leptæna*, and *Spiriferina*; while *Terebratella*, *Zellania*, &c. appear for the first time. Crustacea of the genera *Eryon*, *Æger*, *Glyphea*, &c. are found, and some species are not uncommon. Of the Arachnida, one doubtful example of an aquatic Spider has been recorded.

Insects, or remains of them, are plentiful at certain horizons. None of the forms are very distinct from those now in existence. They include Orthoptera, Diptera, Neuroptera, Coleoptera, and Rhynchota (Hemiptera); and they indicate a temperate climate.

Crinoids such as *Pentacrinus* and *Extracrinus* are locally abundant. In some cases the stems of *Extracrinus* exceed 50 feet in length. Some forms of Echini such as *Cidaris* and *Hempedina*, and of the Coral *Montlivaltia*, are plentiful in places: but as a rule Echini, Polyzoa, and Corals are rare. Many Foraminifera have been recorded.

Lignite is met with here and there, and some plant-remains belonging to the genera *Pachyphyllum* (*Araucarites*), *Otozamites*, &c., have been found. On the whole the Cycadaceæ appear to have been more abundantly preserved than other plant-remains.

### *Zones.*

A study of the fossil contents of the Lias has led palæontologists to make certain divisions or "zones," based upon the succession of the organic remains.

That certain groups of fossils characterize successive stages in the Lias was pointed out by Louis Hunton in 1836. His observations applied to Yorkshire, where he was followed by W. C. Williamson and others.† In the south of England the sequence was noted in 1839 by De la Beche,‡ in 1840 by Strickland,§ and in 1842 by James Buckman.|| It was not, however, until after 1856, when Oppel published his "Juraformation," that any systematic attempt was made to define and follow out these subdivisions in our country. The work of Oppel was based on that of Quenstedt, yet he not only amplified our knowledge of the continental strata, but showed that the main palæontological divisions were applicable to this country. His work has been followed up by that of Thomas Wright¶ and many others.

* See also R. Tate, Geol. Mag. 1871, p. 5.
† See C. Fox-Strangways, Jurassic Rocks of Yorkshire, p. 16.
‡ Report on the Geology of Cornwall, &c., p. 227.
§ Proc. Geol. Soc., vol. iii. p. 315; Trans. Geol. Soc., ser. 2, vol. vi. p. 552.
|| Moxon's Geologist, p. 16; Geol. Chart of the Cotteswold Hills, 1848; Murchison's Geol. Cheltenham, Ed. 2. pp. 41, &c.
¶ Quart. Journ. Geol. Soc., vol. xvi. p. 411.

A prominent species of Ammonite was usually taken as the index to the zone. Ammonites however were not always to be found, and recourse was had in some instances to a Crinoid, a Brachiopod, or other fossil. The value of these zonal divisions has been questioned, because owing to the local absence of Ammonites, and the rarity of other fossils, the zones may often be indeterminable. Moreover the tendency to assign definite limits to them is apt to create a feeling of distrust. There can however be no question of the truth of the general sequence of organic remains in the Lias, a sequence that can be verified by any one who will devote three or four weeks to the Lias cliffs of Dorsetshire. Certain groups will be found in sequence, and experience shows we may look in vain for *Ammonites planorbis* or *A. Bucklandi* in the higher beds of the Lower Lias, and we should be equally at a loss to find *A. capricornus* or *A. Henleyi* in the Basement-beds: yet no one can fix definitely the limits of the several zones.

The local lithological divisions do not necessarily coincide with the limits within which the index-species of zones may occur in abundance. For instance the limestones of the zone of *Ammonites Bucklandi* are locally replaced to a large extent by clay. Nevertheless the succession of the Liassic strata exhibits some fairly persistent types of rock, that accord generally with the fossiliferous horizons. This is the case with the basement-beds both of Lower and Upper Lias, with the rock-beds of the Middle Lias, and with some of the pyritic shales of the Lower Lias.

While some species of Ammonites appear to have a restricted range, there are others that endured for much longer periods, and so do not lend themselves to zonal groupings. Thus the value of selected index-species varies in different areas, for there is no reason to believe that the range of any one species was confined over a large area within the same time-limits. Experience however tells us that when we find our index-species in fair abundance, together with forms usually associated with it, we may confidently assign the strata to the particular zone. To some extent we find that the associated species vary as we trace the beds across country, for species of *Cardinia*, *Hippopodium*, and other forms are prevalent locally at certain stages. Nevertheless the most important factor in the faith in zones is that the incoming of the species of *Ammonites* occurs in a regular sequence, and that there is no inversion in the order of the prominent groups of fossils.

We have no evidence to show that any one zonal species was exterminated before another came in, in fact we find the earlier predominant forms lingering on beside each succeeding species. There is thus a blending of the zones, where the succession is gradual and complete, but this in no ways interferes with the fact of the gradual succession of different forms of life. The great difficulty often is to decide how many zones it may be desirable to indicate. The more detailed study of particular districts shows that we may introduce zones of a more or less local character, zones which are established on the evidence of the prevalence of a

particular species within certain ascertained limits. So far as possible these zones will be indicated in the course of this work, for they may be useful in instituting comparisons with strata elsewhere; but it must be clearly borne in mind that the non-recognition of any zone, owing to the absence of the index-species, is no proof of any break in the succession.

Zones marked by one species may be represented locally by a different, and perhaps closely allied form, as in the case of *Ammonites capricornus* and *A. Henleyi*, of *A. Turneri* and *A. semicostatus*, or of *A. planorbis* and *A. Johnstoni*, &c.

The inability to define the stratigraphical limits of zones in a series of comparatively uniform clays, renders it difficult in many cases to prove their continuity, and it may be admitted that the *strata* assigned to particular zones in different parts of the country cannot be regarded as precisely or entirely synchronous. It is however enough to admit the general contemporaneity of beds, without attempting to fix particular limits for sediments that were continuously deposited.

It is indeed remarkable that throughout the Lias, which is essentially an argillaceous formation, with here and there more or less marked bands of limestone and with local divisions of sandy strata, there is such a marked change in the forms of Ammonites, not to mention other species, that are met with at successive stages. In the higher divisions of the Lower Lias and the lower portion of the Middle Lias there is an unbroken series of clayey sediments, and we have no reason to conclude that their deposition was other than tranquil and uniform over considerable areas. Yet we find a tolerably distinct series of Ammonites coming on in succession, and other changes in the fauna, independent of the conditions of sedimentation.* Such a repetition of similar conditions attended by gradual changes in the character of the fauna is met with in the Chalk. It seems probable that the changes were brought about by slow, and perhaps occasionally by rapid, subsidence, connecting areas previously separated to a greater or less extent; whereby different species became introduced, and in some cases those already existing in the area may have become modified. Physical changes that affected the food-supply of Mollusca no doubt influenced the forms of life. Moreover species that had a prolonged individual existence became modified in their old age, so that certain so-called species are admitted by some authorities to represent stages of growth as in the case of *Ammonites capricornus* and *A. Henleyi*; while many other species are linked together by intermediate or "exallagous" forms to which the name of "mutations" is given.†

### *Formation of the Rocks.*

There are many stratigraphical facts that lead to the conclusion that the Lias limestones were to a considerable extent sedimentary

* See also R. Tate, Quart. Journ. Geol. Soc., vol. xxvi. p. 401; Tate and Blake Yorkshire Lias, p. 217; and H. B. W., Proc. Geol. Assoc, vol. xii. p. 306.

† See J. F. Blake, Proc. Geol. Assoc., vol. xii. p. 277. The word "exallagous" was introduced by J. E. Marr, Natural Science, April 1892, p. 125.

in their character, and that they were derived more or less mechanically from the waste of the older rocks that formed land-areas during the Liassic period. The limestones themselves are for the most part earthy and argillaceous, so that the materials constituting the mass of the Liassic strata might have been derived from the waste of Palæozoic limestones and shales; these old rocks being ground into calcareous mud by the breakers on the sea-shore or along the borders of a turbulent estuary. This view is indeed maintained by Messrs. Tate and Blake, who speak of the calcareous portions of the Lias being derived from pre-existing strata, and not directly from organic remains.* At the same time throughout the Lias the strata bear evidence of tranquil deposition, and only occasionally has any evidence of current-bedding been observed.

It will be noted that the limestones which occur at the base both of the Lower and Upper Lias are locally termed Fish and Insect Limestones, their peculiar characters being originally made known by the labours of the Rev. P. B. Brodie and H. E. Strickland. Where definite evidence is obtained of the proximity of old land as in Glamorganshire and along the Mendip Hills, limestones are prominently developed, sometimes to the exclusion of clays and shales;† and in the Radstock area, where the beds are much attenuated, the higher stages of the Lower Lias, elsewhere mainly represented by clay, are there for the most part limestone.

The general evidence goes to prove that the limestones, and the alternations of limestone and shale, were accumulated in water that was shallower than that of the mass of the clays.‡ As we ascend the series in the Lower Lias, the limestones become less and less prominent, and the upper portions of the series are almost entirely argillaceous. Of a clayey nature also is the base of the Middle Lias; but higher up there are alternations of sands and clays, and, at the top, the impure and sometimes highly ferruginous limestones known as the Marlstone. Again in the Upper Lias the series commences in a thin group of limestones and clays and passes up into a mass of clays and shales. Thus the conditions appear to be as follows:—

| | | |
|---|---|---|
| Upper Lias | Clays | *Deeper water.* |
| | Limestones and clays | *Shallower water.* |
| Middle Lias | Marlstone | |
| | Sands and clays | |
| | Clays | *Deeper water.* |
| Lower Lias | Clays | |
| | Limestones and clays | *Shallower water.* |

The occurrence of shallower-water deposits in a continuous series of strata may be attributed partly to changes in currents brought about by the shallowing of the sea-bed, owing to increase of sediment, and partly to the effects of denudation, whereby fresh rocks were brought under the influence of the erosive agents

* Yorkshire Lias, p. 215.

† See also De la Beche, Mem. Geol. Survey, vol. i. pp. 276–278.

‡ In the Museum of Practical Geology there is a specimen of Lower Lias limestone from Barrow-on-Soar, that shows minute current-bedding: a feature of rare occurrence in that formation.

acting along a coast-line. Similar effects might be produced locally by slight depression.

The evidence of this shallower-water formation of the limestones, is on the whole stratigraphical rather than palæontological, and it must not be forgotten that there are areas, such as Lyme Regis and Rugby, where the limestones at the base of the Lias are well-developed, and where we have no evidence for or against the proximity of land. Again on the eastern borders of the Bristol coal-field, where the Lias comes occasionally into direct contact with the Palæozoic rocks, limestones are not prominently developed. The occurrence of Insects is suggestive of the proximity of land, although they may have been blown out to sea, or floated down rivers. Occasional small masses of lignite are found, and Gasteropoda as well as Saurians, are fairly abundant in some of the limestones.

The questions that arise concerning the limestones are to what extent the calcareous mud was deposited more or less mechanically or precipitated chemically; and to what extent the calcareous matter was derived by mechanical abrasion, and by the accumulation and decay of organisms and of material voided by them.

The stratigraphical evidence shows that there must have been considerable though variable accumulations of highly calcareous mud. The limestones and shales of the Lower Lias occur in more or less rapid alternation. Some of the limestones, found in persistent layers, present markedly irregular surfaces, being more or less protuberant or nodular, while the separating bands of clay or shale contain nodules and lenticular masses of limestone. It seems most reasonable to believe that in these cases the calcareous matter ségregated from the more argillaceous portions of the mud. The same would have been the case with the nodular limestones or cement-stones and septaria that occur in the mass of the clays, and in particular with those Upper Lias nodules that enclose remains of Fishes, &c.* In other cases where the limestones occur in comparatively even bands, they are usually more or less striped and laminated, and they pass by insensible gradations into calcareous shale. Such is the case with the Insect Limestones and associated strata in the Lower Lias, and their sedimentary origin can hardly be doubted.

This subject of the more or less detrital origin of the Lias limestones has occupied my attention during the past eight years, but I was unaware, until the above remarks were written, that Prof. Sollas, had in 1879, published some notes on the same subject. These notes were printed in a paper dealing with the Silurian district of Rhymney, near Cardiff.† After stating the evidence on which he concludes that the cornstones of the Old Red Sandstone originated from mechanically-formed sediments, he points out that there are other instances in which limestones have been derived "from sediments which have been carried in suspension and strewn out in deposits, in just the same fashion as

* See De la Beche, Researches in Theoretical Geology, pp. 95, &c.

† See Quart. Journ. Geol. Soc., vol. xxxv. p. 492; see also vol. xxxix. p. 614.

clay or any other mechanical sediment may be. The conglomerates of Mountain Limestone formed on ancient beaches of the Lias are a case in point; and the pebbles of these conglomerates are frequently as well rounded as any we can find on a beach at the present day. What has become, then, of the asperities and angles which have been worn away during the rounding of the pebbles? The usual reply is, 'Dissolved in the surrounding sea-water;' but it seems to me that there is always the alternative possibility that it has been carried away as mud in suspension, just like any other mud; and if so, the deposition of such calcareous mud would go far towards explaining the occurrence of calcareous septaria and other nodules, which so frequently occur in red deposits like those of the Old Red Sandstone and the Trias, as well as in the formation of the muddy Lias limestones of Penarth Cliffs, which, with their flat even bedding and numerous intercalations of black shales, certainly do not suggest an organic origin. A few oysters and such-like shells may have contributed to their growth; but their general appearance certainly is that of strata formed from sediment carried in suspension, and very different from that presented by a truly organic calcareous rock."*

The preservation of conglomeratic limestone-beds in the Lias, even where we have evidence of the proximity of old land is rare, and equally so is the evidence of transition between such conglomeratic beds and the ordinary limestones. As will be noted in the account of the Lias of South Wales, the limestones sometimes contain chips of chert derived from the Carboniferous Limestone, when no pebbles of that older rock are to be seen. Again on the borders of the Mendip Hills, the Lias limestone contains pebbles of quartz derived from the Old Red Conglomerate, while pebbles of Carboniferous Limestone may not always be found. Of the limestone-conglomerate, some of the best examples are met with at Vallis, near Frome, and at Southerndown, near Bridgend.

It seems to me that the Cotham or Landscape Marble that occurs at the base of the White Lias (Rhætic Beds) affords evidence both of sedimentary deposition and of subsequent concretionary action. In the more persistent layers of rock we find only compact and banded limestone with no arborescent markings. Thus the dark argillaceous sediments that prevailed previously, when the Black *Avicula-contorta* Shales were laid down, had some later influence amid the purer calcareous mud that prevailed during the formation of the White Lias. Where the arborescent limestone occurs, it is in the form of impersistent masses, and these are characterized by a crinkly surface that appears due to contraction, because thin films that correspond to the irregularities of the surface, may often be flaked off. I have suggested that the arborescent markings were produced by the irregular admixture of layers of dark mud amid the lighter calcareous mud during the consolidation and shrinking of the sediments; the shrinking as a rule only affecting the upper portions of the layer.†

* See also De la Beche, Mem. Geol. Survey, vol. i. pp. 284, 293.

† Geol. Mag. 1892, p. 110.

Mr. Allan Dick, who has kindly examined a specimen of Cotham Marble, tells me that dark portions of the stone are not due to the presence of manganese- or iron-ores, but are probably due to carbonaceous matter.

The probable sedimentary origin of some of the Triassic limestones, has been suggested by Mr. Horace T. Brown and myself.* An analysis of a limestone from Litton, near Chewton Mendip, was made by Mr. Brown, and subsequently he obtained specimens of similar rocks from Chew Stoke, and had a series of sections cut for microscopic examination. Referring to the sections of these rocks, Dr. Sorby wrote, "There appears to me little or no doubt that a large part of the material has been derived from the Carboniferous Limestone * * * Some of the grains are clearly fragments of an older limestone, which was not only in some places oolitic, but which I think also shows clearly the presence of Foraminifera like those in Carb. Limestone. There are also fragments that might be derived from such a rock, as *broken joints of Encrinites*, and probably of Coral and Shell. On the whole it is an excellent case of what I have often thought must occur in some cases, viz., a mud derived from a limestone rock."†

With regard to the chemical aspect of the subject more information is desirable. The small amount of carbonate of lime held in sea-water (the per-centage in the total saline matter being 0·345), has led to the belief that much of this material, brought down by rivers, is converted into sulphate of lime, the per-centage of which among the saline ingredients is 3·6. From the sulphate of lime it is maintained that marine organisms derive the substance they need for their hard parts, while their ultimate decomposition brings about a precipitate of carbonate of lime. These conclusions, however, do not affect the question of the possible sedimentary origin of some calcareous deposits.

Prof. Dittmar has pointed out that alkaline sea-water, if given sufficient time, will take up carbonate of lime in addition to the matter it already contains. The solvent powers of sea-water, due to the presence of free carbonic acid, do not appear to be very great, for although this gas is obtained from the decay of marine plants and animals, from the atmosphere, and possibly from submarine volcanic sources, its presence in a free state in sea-water is the exception.‡ Mr. W. S. Anderson says, "The soluble action of sea-water on amorphous carbonate of lime has nothing to do with carbonic acid. An artificial sea water, free from carbonic acid and carbonates of any kind, will dissolve up quite as much. It is distinctly confined to the soluble action of the salts present."§

Prof. Sollas has suggested that "rivers sometimes bear to the sea considerable quantities of undissolved calcareous matter derived from the formations through which they flow."|| This is a matter that requires confirmation, for it is known that carbonate of lime is more readily soluble in fresh-water than in sea-

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* Geol. Eng. and Wales, Ed. 2, p. 233.

† Letter to Mr. H. T. Brown. See also Sorby, Address to Geol. Soc., 1879; and Prestwich, Geology, vol. i. p. 110, vol. ii. p. 318.

‡ Report on the voyage of H.M.S. "Challenger"; Physics and Chemistry, vol. i. pp. 203–222; see also J. Murray, Nature, Feb. 28, 1889, p. 426; *Ibid.*, June 12, 1890, p. 165; and A. Agassiz, Mem. Amer. Acad. Arts & Sc., vol. xi., pp. 114, 125, &c.

§ R. Irvine and G. S. Woodhead, Proc. R. S. Edin., vol. xv. p. 308, vol. xvi. p. 324; R. Irvine and G. Young, *Ibid.*, vol. xv. p. 316; and J. G. Goodchild, Geol. Mag. 1890, p. 76, and Trans. Cumberland and Westmorland Assoc., No. xvi., 1891.

§ Proc. R. S. Edin. vol. xvi. p. 322. See also W. G. Reid, *Ibid.*, vol. xv. p. 151.

|| Quart. Journ. Geol. Soc., vol. xxxix. p. 614.

water. Near Coral-reefs much calcareous matter is held in suspension by the sea; and Mr. John Murray remarks that sea-water apparently is unable to retain in solution more carbonate of lime than is usually found present in it.

Considering therefore the evidence that carbonate of lime is not rapidly dissolved in sea-water, and that we have evidence of accumulations of limestone not far distant from land-areas, it may reasonably be inferred that under certain conditions there may be sedimentary deposits of calcareous mud as well as chemical precipitates. These conditions might take place especially when the limestone-particles were mixed with argillaceous matter, and more limestone was worn from the old cliffs, than could be dissolved by the sea-waters.

### *Microscopic Structure.*

Microscopic examination of Lias limestones shows the presence of granular calcareous matter and of rolled fragments of Crinoids, &c., in some cases probably derived from older strata, such as the Carboniferous Limestone. The Lias limestones, however, are sometimes more or less crystalline in character, and therefore, while regarding much of the material as deposited as a sediment, no doubt a certain amount of carbonate of lime was precipitated from solution (during consolidation or long subsequently), while other portions of the calcareous mud were due to the decay of organisms as well as to the voidings of marine animals.

Dr. Sorby, who has investigated the microscopic structure of some Lias limestones, remarks as follows:—

"On the whole the organic constituents of the coarser-grained beds of the Lias are closely like those of similar beds of Oolitic age, though there is a relatively less amount of fragments of aragonite shells and corals. By far the greater bulk is made up of joints of *Pentacrinus*, which in some cases constitute nearly the whole rock. Next in abundance are fragments of Brachiopods and Oysters and shell-prisms; but Foraminifera and portions of Belemnites and bone also occur. The somewhat finer-grained beds differ mainly in the comparative absence of joints of *Pentacrinus*, whilst the finest-grained were probably derived from completely ground down or decayed shells, mixed with much mineral impurity and more or less coloured by bituminous matter * * * Grains of glauconite or some other analogous green mineral are not uncommon, and it often fills up the hollow spaces in the joints of *Pentacrinus* and in shells, so as to show their structure in a very striking manner. Occasionally very crystalline, non-radiate, oolitic grains are met with, which have all the characters of recrystallized, small, concentric, aragonite concretions."*

Further reference will be made to the ironstones that show oolitic structure. (See p. 300.) It may be mentioned that occasionally in the Lower Lias and more frequently in the Marlstone Rock-bed, the limestone is "iron-shot." This appearance is sometimes due to the presence of oolitic granules, but more often to tiny organic fragments replaced by iron-ore. (See p. 127.) In some instances all traces of original structure are lost.

* Address to Geol. Soc. 1879, p. 54.

Sections of Liassic limestone have been examined under the microscope by Mr. J. J. H. Teall, whose notes are embodied in the following statement :—

The fine-grained and more or less earthy limestones of the Lower Lias, of which examples were examined, from Street and Shepton Mallet in Somersetshire, and from Wigston in Leicestershire, show in section granular calcareous matter. Organic fragments belonging to Crinoids and Echini may be noticed, and these often appear in a matrix of crystalline calcite, the fragments sometimes forming nuclei of large individual fragments of calcite, as in the Doulting stone (Inferior Oolite).

The granular and shelly limestones of the Lower Lias of Sutton in Glamorganshire, of Shepton Mallet and Downside near Wrington in Somersetshire, show a matrix of fine-grained semi-transparent and partially crystalline calcareous matter, with obscure and more or less rolled organic fragments.

The ironshot limestone (Marlstone) of the Middle Lias of Trent, near Yeovil, showed many organic fragments and a few grains of ferruginous oolite. The matrix was composed of calcite, partly granular and partly crystalline; secondary calcite often occurring in optical continuity with the original organic fragments.

The green earthy limestone (Marlstone) of Hornton, near Edge Hill, in Warwickshire, showed rolled organic fragments in a matrix of crystalline calcite.

An argillaceous limestone from the Upper Lias of Brent Knoll in Somersetshire, showed organic fragments (Foraminifera, &c.) in a dull grey granular matrix.

The Lias clays seem to be analogous to the blue terrigenous muds described by Messrs. Murray and Renard: such deposits are extensively formed around the great continents and continental islands, and they are coloured blue by organic matter and by sulphide of iron.*

*Subdivisions of the Lias.*

The principal classifications of the Lias adopted by different authors having been tabulated by Mr. Strangways,† it is unnecessary to repeat them here; but it will be useful to state in concise form the grouping adopted in this Memoir.

On palæontological grounds it is indeed difficult to separate the Middle and Lower Lias, and different authorities have adopted different zones for the upper limit of the Lower Lias. Thus Wright, following Oppel, took the zone of *A. raricostatus* as the top of the Lower Lias, and the same horizon was followed by Tate and Blake.‡ Tate however admitted that the line of demarcation might be drawn between the zones of *A. obtusus* and *A. oxynotus.*§ Prof. Judd, following Quenstedt, took the junction between the zones of *A. capricornus* and *A. margaritatus*, a course that on stratigraphical grounds is the most convenient, although not unattended with difficulty, and it is one also that coincides most nearly with the original divisions made in the Lias by John Phillips.‖ This grouping is followed in the present Memoir.

* Report of the "Challenger," vol. i., Part 2, 1885.

† Jurassic Rocks of Yorkshire, vol. i. p. 29.

‡ Yorkshire Lias, p. 16. A. de Lapparent in his Traité de Géologie (1893), p. 953, follows the same grouping of the Middle Lias as Oppel; and employs the name *Charmouthian* for the zones *A. armatus* to *A. spinatus* (inclusive).

§ Quart. Journ. Geol. Soc., vol. xxvi. p. 400.

‖ Geol. Rutland, p. 46.

TABLE SHOWING THE PRINCIPAL ZONES IN THE LIASSIC ROCKS.

| | | Principal Zones. | General Grouping of Zones adopted. |
|---|---|---|---|
| Inferior Oolite. | Midford Sands (passage-beds) | *Ammonites opalinus* | *A. opalinus.* |
| Upper Lias | Clays with cement-stones | *A. jurensis*<br>*A. communis* | *A. jurensis.*<br>*A. communis.* |
| | Limestones and clays (Basement Beds) | *A. serpentinus*<br>*A. annulatus* (Transition Bed) | *A. serpentinus.* |
| Middle Lias | Marlstone and sands (Rock Bed and Iron-stone). | *A. spinatus* | *A. spinatus.* |
| | Micaceous clays and sands | *A. margaritatus* | *A. margaritatus.* |
| Lower Lias | Clays with occasional bands of limestone | *A. capricornus* and *A. Henleyi* | *A. capricornus.* |
| | | *A. Ibex*<br>*A. Jamesoni*<br>*A. armatus* | *A. Jamesoni.* |
| | | *A. raricostatus*<br>*A. oxynotus*<br>*A. obtusus* | *A. oxynotus.* |
| | Limestones and clays | *A. semicostatus* and *A. Turneri*<br>*A. Bucklandi*<br>*A. angulatus* | *A. Bucklandi.* |
| | | *A. planorbis* | *A. planorbis.* |

# LOWER LIAS.

## General Description.

The Lower Lias consists in its lower portion of layers of blue and grey limestone, more or less argillaceous. These layers occur sometimes in even and sometimes in irregular bands often nodular and interrupted, and they alternate with blue and brown marls, clays, and shales; the whole presenting, as Conybeare remarked, a "riband-like appearance." These beds, as a rule, rest conformably on the Rhætic Beds; and where the White Lias or upper portion of the Rhætic Beds is prominently developed, as in the south-west of England, there is usually a marked contrast in the colour and texture of the strata belonging to these two divisions.

The higher portion of the Lower Lias consists of blue, more or less micaceous clays, shales, and marls, with occasional septaria, nodules and bands of earthy and shelly limestone, and sandy layers. There is no rigid plane of demarcation between them and the mass of limestones beneath, while the clays pass upwards into the lower beds of the Middle Lias, with no lithological break or divisional-line. The dark shaly beds are occasionally bituminous.

The limestone-beds naturally form the higher grounds, rising in escarpments, while the clays occupy low-lying tracts that merge into those formed by the lower beds of the Middle Lias.

Local modifications of the Lower Lias occur on the borders of the Mendip Hills near Shepton Mallet, on Broadfield Down, and at Sutton and Southerndown in Glamorganshire, where the limestones, usually pale in colour, become granular in texture and more or less conglomeratic, while the clayey partings are absent or very meagrely represented. Peculiar siliceous varieties of the Lias occur near Chewton Mendip and East Harptree; while in the Radstock area the Lower Lias is much attenuated. Such changes are natural enough, for they are noticeable in the neighbourhood of those Palæozoic rocks which formed land-areas during the deposition of the strata.

The total thickness of the Lower Lias varies from about 485 feet in Dorsetshire to about 960 feet in Gloucestershire, 465 feet in Northamptonshire, and about 700 feet in Lincolnshire; but it is much less near Bath.

These beds have been subdivided into Zones which may be conveniently grouped as follows:—

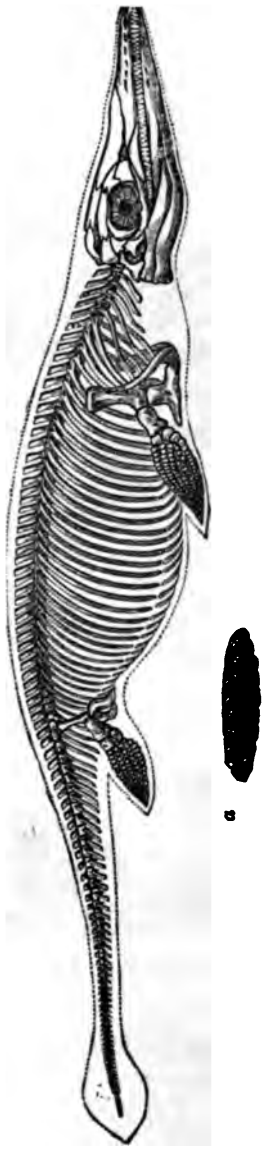
| General Grouping. | Zones. | Chief Lithological Characters. |
|---|---|---|
| *Ammonites capricornus.* | *Ammonites capricornus* and *A. Henleyi.* | Clays with reddish-coloured ironstone nodules. |
| *A. Jamesoni* | *A. Ibex*<br>*A. Jamesoni*<br>*A. armatus* | Dark clays and pyritic shales, with occasional sandy beds, and ironstone nodules. |
| *A. oxynotus* | *A. raricostatus*<br>*A. oxynotus*<br>*A. obtusus* | Dark clays and shales, with much iron-pyrites. |
| *A. Bucklandi* | *A. semicostatus* and *A. Turneri.** <br>*A. Bucklandi*<br>*A. angulatus* | Blue argillaceous limestones and clays — mainly clay or marl in some localities and with ironstone at Frodingham. |
| *A. planorbis* | *A. planorbis* | Even-bedded limestones and shales, pale marly limestones and fissile marls. |

These are the broad general divisions that may be traced across the country, and throughout it the chief zones have been identified, though in many localities, owing to the absence of sections, particular zones have not at present been distinguished.

Nowhere in the Lower Lias is there any marked band of rock that can be traced persistently for any great distance. Generally speaking the lithological characters assigned to the zones are fairly persistent, but there is no sufficiently definite association of beds of particular lithological character, such as would enable us to fix horizons independently of organic remains. Some of the "Insect limestones" in Warwickshire, and adjoining parts of Worcestershire and Gloucestershire, present characters that enable us to identify the division to which they belong, and it will be seen that the great masses of limestone, wherever they occur, belong to the lower part of the Lower Lias: but the great developments of limestone, belonging to the zones of *Am. angulatus* and *A. Bucklandi,* such as we see at Lyme Regis, near Bridgend, at Harbury and Rugby, are more or less local, passing elsewhere into clays with occasional bands of limestone. Higher up the dark pyritic shales are suggestive of beds belonging to the zones of *Am. oxynotus* or *A. armatus,* &c., while clays with ochreous nodules are suggestive of the zones of *A. Jamesoni* and *A. capricornus.* This argillaceous division is for the most part well developed, excepting in the neighbourhood of Radstock in Somersetshire, where some of the subdivisions are represented by single bands of limestone.

* Wright considered the zones of *A. Turneri* and *A. semicostatus* as the upper part of the zone of *A. Bucklandi.* Lias Ammonites, Palæontograph. Soc., pp. 284, 286.

FIG. 2.



a

*Ichthyosaurus communis*, Conyb.; and Coprolite (*a*), Lyme Regis.

FIG. 3.

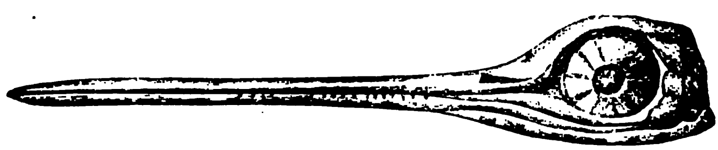
*Plesiosaurus dolichodirus*, Conyb., Lyme Regis.

## Lower Lias Saurians.

Fig. 4.

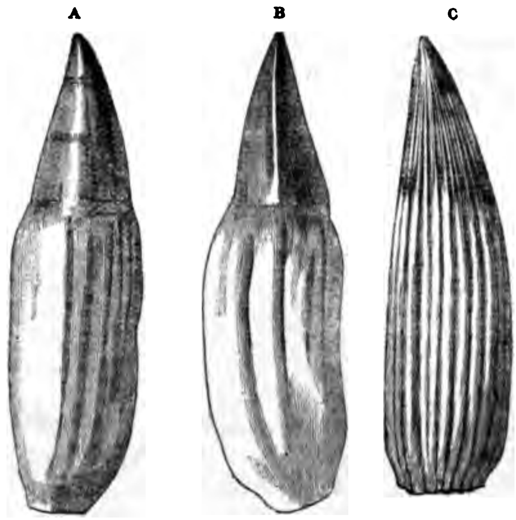
Skull of *Ichthyosaurus communis*, Conyb., Lyme Regis.

Fig. 5.



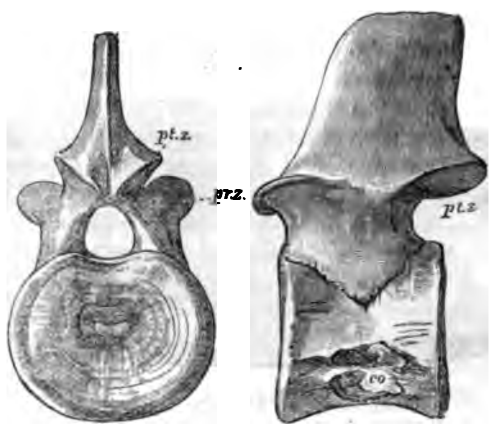
Skull of *Ichthyosaurus latifrons*, König., Barrow-on-Soar, ⅛ nat. size.

FIG. 6.




A. B. Teeth of *Ichthyosaurus* (*Temnodontosaurus*) *platyodon*, Conyb., Lyme Regis. C. Tooth of *Ichthyosaurus communis*, Conyb., Lyme Regis.

FIG. 7.

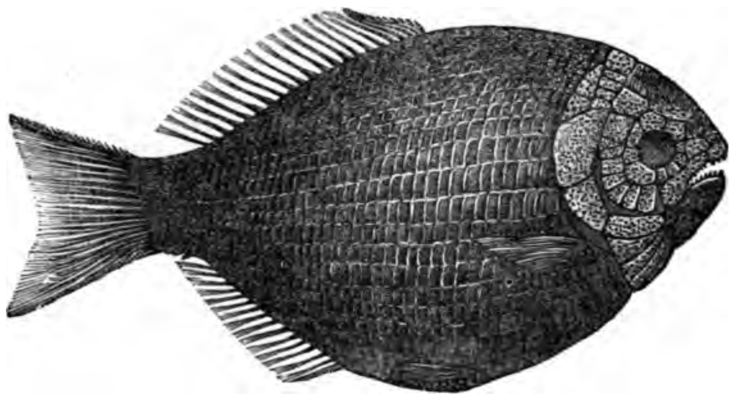



Cervical vertebra of *Plesiosaurus Hawkinsi*, Owen, Lyme Regis.

The Lower Lias of Lyme Regis, Street near Glastonbury, and Barrow-on-Soar, is noted for its Saurian remains, probably because the beds have been extensively quarried or otherwise opened up at these localities. Many species of *Ichthyosaurus* and *Plesiosaurus* have been obtained; some of the forms of Plesiosaurus being now known under the generic names of *Eretmosaurus* and *Thaumatosaurus* (see Figs. 2–7, pp. 37–39). The remains of Pterodactyl are now included under one species known as *Dimorphodon macronyx.*

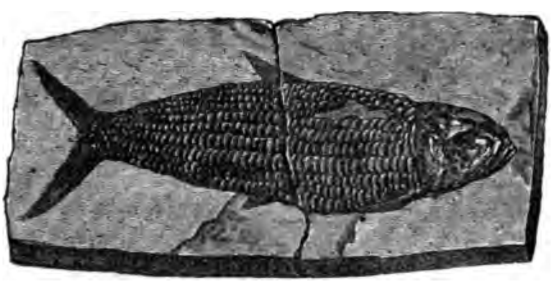
## Lower Lias Fishes.

Fig. 8.



*Dapedius pholidotus*, Ag., Lyme Regis.

Fig. 9.



*Pholidophorus Bechei*, Ag., Lyme Regis.

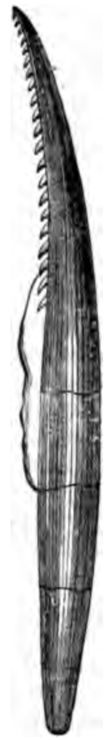
A great many Fishes have been obtained, principally from the neighbourhood of Lyme Regis, but some also from Barrow-on-Soar and other localities. Among these we may note *Acrodus Anningiæ* and *A. nobilis* (teeth of which are known familiarly as "Leeches," see Fig. 10), *Dapedius* (Fig. 8), *Chondrosteus,*

*Eugnathus, Hybodus reticulatus* (see Fig. 11), *Pholidophorus Bechei* (Fig. 9), &c.

FIG. 10.

Teeth of *Acrodus Anningiæ*, Ag., Lower Lias, Lyme Regis.

FIG. 11.



Dorsal Spine of *Hybodus*, Lower Lias, Lyme Regis.

Coprolites of both Fishes and Saurians have been obtained.* The larger coprolites of Saurians contain fish-scales, bones of small Saurians, and occasionally water-worn pebbles.†

Among the Crustacea we find *Scapheus* (Fig. 38), a genus confined to the Lias, and *Eryon* which appears in this country for the first time. Foraminifera seem to be more abundant than in other divisions of the Lias.

Among the Mollusca *Ammonites* and *Belemnites* appear, for they are not known in the Rhætic Beds of this country. Gasteropods are represented by many genera, including *Amberleya* (*Eucyclus*), *Cerithium, Chemnitzia, Cryptænia, Pitonnillus, Pleurotomaria, Trochus, Turbo,* &c. *Dentalium* also occurs.

With regard to the distribution of the fossils of the Lower Lias, it will be found that the local abundance of certain genera and

* See Buckland, Trans. Geol. Soc., ser. 2, vol. iii. p. 223.

† Dr. Ruest of Freiburg has obtained Radiolarians in Coprolites from the Lias [or Rhætic Beds?] of Gloucester. Palæontographica, vol. xxxi. 1885. See also Lydekker, Cat. Foss. Reptilia Brit. Mus., Part 2, p. 114; and T. Hawkins, Great Sea Dragons, 1840.

species, renders it impossible to give a list of the common and characteristic fossils that would apply to all localities.

Some of the Ammonites are widely distributed (geographically) as *A. planorbis* (Fig. 12), *A. Johnstoni*, *A. angulatus* (Fig. 13), *A. semicostatus*, *A. oxynotus* (Fig. 16), *A. armatus* (Fig. 18), *A. Henleyi* (Fig. 24), *A. capricornus* (Fig. 26), &c.

The most common fossils are *Gryphæa arcuata* (*incurva*) known as "Devil's toe-nails" (Fig. 35), *Lima gigantea* (Fig. 28), *Ostrea liassica* and *Pentacrinus basaltiformis* (Fig. 39) in the lower beds; while *Pleuromya costata, Inoceramus ventricosus* and *Belemnites* (of many species) are abundant in the upper beds. Other species such as *Cardinia Listeri* (Fig. 30), *C. ovalis*, *Hippopodium ponderosum* (called the horse's or ass's foot by the country people, Fig. 29,) and *Montlivaltia Victoriæ* are locally very abundant: but *H. ponderosum* occurs in the zone of *A. angulatus* in Yorkshire, much lower than it has been found elsewhere in England.* *Lima pectinoides* and *Unicardium cardioides* occur at various horizons, and so also do *Rhynchonella calcicosta* and *R. variabilis* (Fig. 37), but the latter species is referred to by Messrs. Tate and Blake as "a refuge for the uncertain forms obtained in the Lias." *R. plicatissima* seems to be the prevalent form in the lower beds in Yorkshire,† and both this species and *R. calcicosta* have been recorded by many geologists under the general name of *R. variabilis*.

The great abundance of *Ostrea liassica* at the base of the Lower Lias, has given rise to the name Ostrea-beds, and it is sometimes accompanied by "*Ostrea irregularis*," which assumes various forms according to the organism to which it frequently attached itself. The prevalence of large forms of *Lima gigantea* in the higher beds of limestone, has led to the term "*Lima*-beds," generally synonymous with the zones of *A. Bucklandi* and *A. angulatus*. Again *Spiriferina Walcotti* (Fig. 36) is locally abundant near Radstock, and we have the term "Spirifer Bank;" so also there are the *Cardinia*-beds and *Hippopodium*-beds of the western midland counties, which do not, like the *Ostrea*- and *Lima*-beds, mark very definite stratigraphical horizons. The Saurian beds, Insect and Crustacean beds, and Foraminifera zone may occur at different horizons, although locally applied to some particular bed, as will be noted in the sequel. Saurian remains are mainly found in the lower beds, comprising the limestones of the zones of *Ammonites planorbis* and *A. Bucklandi*. At Lyme Regis they are found mainly in the zone of *A. Bucklandi*, but also in some of the overlying clays; at Street, Curry Rivell, Langport, and in parts of Gloucestershire, Warwickshire, and Leicestershire in the zone of *A. planorbis*; while in Yorkshire such remains are more abundant in the Upper Lias.

Belemnites ("thunderbolts") are rare in the limestones, indeed they are not known in the lower portion of the zone of *Ammonites*

* We have the record only of *Hippopodium* (cast) from Lower Lias limestone at Queen Camel.

† The Yorkshire Lias, p. 421.

*planorbis*, but they are common enough in the clay-series, as in the Belemnite Beds of Golden Cap. Hooklets of *Belemnites* have been found by Dr. Hinde in the zone of *A. angulatus* at Street; while no other portions of Belemnite have at present been found at that locality. (See p. 81.) The term Belemnite Beds was applied in Gloucestershire by Prof. Tate to the zones of *A. raricostatus, A. oxynotus,* and *A. obtusus;* although, according to his own lists, Belemnites are more abundant in the beds grouped by him in the zone of *A. Jamesoni,** and this appears to be the case generally. Dumortier has grouped the beds from the zone of *A. Jamesoni* to that of *A. margaritatus* inclusive, under the "zone of *Belemnites clavatus,*" thus including portions of our Lower and Middle Lias.†

Small examples of *Gryphæa arcuata (incurva)* occur sparingly in the zone of *A. planorbis,* but the larger forms are most characteristic of the higher portions of the Blue Lias series, where they often occur in clusters at different horizons. At Fretherne in Gloucestershire particularly fine specimens are abundant. The form of this species is liable to variation, and in the higher beds of the Lower Lias, as at Cheltenham, we meet with the variety known as *G. obliquata;* but *G. cymbium* also occurs. In a large series of specimens from one locality, many varieties may be noticed, and the intimate connexion of the several species may be admitted. These varieties were studied and illustrated by the late John Jones of Gloucester.‡

On coast-sections where we have an opportunity of studying the beds in section and in plan, as they are exposed in cliffs and in ledges or platforms on the foreshore, it is instructive to observe the distribution of the fossils. Such is the case on the Glamorganshire coast between Dunraven and Aberthaw, where the Lower Lias is continuously exposed for several miles in cliffs and in pavements. There we may notice how the organic remains occur in groups or colonies, abundant now and again at various levels. We can picture the evidence obtained in a quarry, where a *Pentacrinite*-bed, a *Gryphæa*-bed, and a *Lima*-bed might be noted in succession; but here on the foreshore we may observe groups of these fossils, sometimes in clusters, at other times intermingled, and at many different horizons, while the same bed appears quite unfossiliferous over the greater portion of its exposure. Such evidence warns us not to place too great reliance on the persistency of fossil-beds, and it explains why organic remains abundant at a certain locality at one time, have become rare later on, when the beds have been extensively worked. In this instance a number of fossil-beds are united in one or two zones (*A. angulatus* and *A. Bucklandi*). The evidence that may be obtained in places, suggests that fossils may sometimes be distributed in groups or clusters by currents that left no mark on the finer sediments.

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* Quart. Journ. Geol. Soc., vol. xxiii. p. 306; vol. xxvi. p. 398.
† Etudes pal. Dépots Jurassiques du Bassin du Rhône, Part III. p. 10.
‡ Proc. Cotteswold Club, vol. iii., series of plates issued separately in 4to.

## Lower Lias Cephalopoda.

Fig. 12.

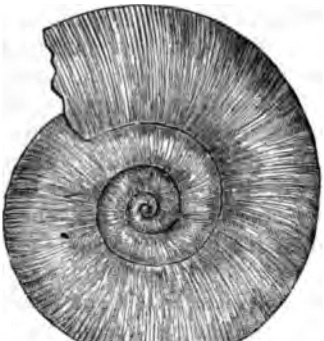

Fig. 13.

Fig. 15.

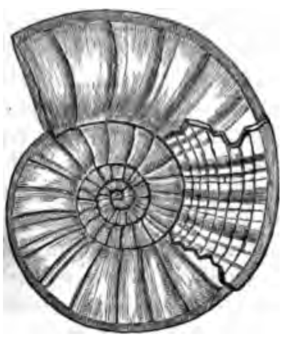

Fig. 14.

Fig. 16.

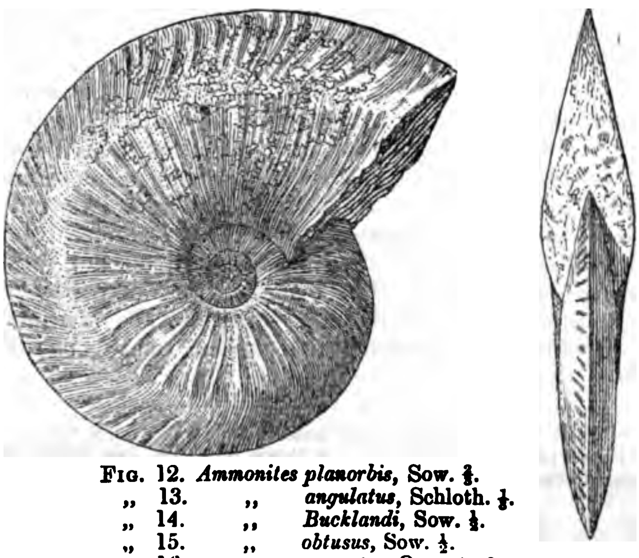

Fig. 12. *Ammonites planorbis*, Sow. $\frac{2}{3}$.
„ 13. „ *angulatus*, Schloth. $\frac{1}{3}$.
„ 14. „ *Bucklandi*, Sow. $\frac{1}{2}$.
„ 15. „ *obtusus*, Sow. $\frac{1}{2}$.
„ 16. „ *oxynotus*, Quenst. $\frac{2}{3}$.

The more abundant and characteristic fossils of the several zones in the Lower Lias may be grouped as follows, and we may look to the prevalence of the index-species to mark the particular zone:—

Zone of AMMONITES PLANORBIS (Fig. 12).

Ammonites Johnstoni.
Avicula cygnipes (Fig. 34).
Lima gigantea (small examples) (Fig. 28).
Modiola minima (Fig. 32).
Ostrea liassica.
—— multicostata.
Pecten pollux.
Pleuromya crowcombeia* (Fig. 33).
Cidaris Edwardsi.
Hemipedina (several sp.).

Zones of AMMONITES ANGULATUS (Fig. 13), A. BUCKLANDI, (Fig. 14), A. SEMICOSTATUS, and A. TURNERI.

Ammonites bisulcatus.
—— Bonnardi.
—— Charmassei.
—— Conybearei.
—— rotiformis.
—— sauzeanus.
Belemnites acutus.
—— infundibulum.
Nautilus striatus.
Cryptænia rotellæformis.
Pleurotomaria anglica (Fig. 27).
Avicula inæquivalvis (sinemuriensis).
Cardinia concinna.
—— Listeri (Fig. 30).
—— —— var ovalis.
Gryphæa arcuata (incurva) (Fig. 35).
Lima gigantea (large specimens from 3 to 10 in. across) (Fig. 28).
—— Hermanni.
—— punctata.
Modiola hillana.
Myoconcha psilonoti.
Pecten calvus.
—— lunularis (liasinus).
—— textorius.
Pholadomya ambigua.
—— glabra.
Pinna Hartmanni.
Pleuromya crassa.
Unicardium cardioides.
Rhynchonella calcicosta.
Spiriferina Walcotti (Fig. 36).
Pentacrinus basaltiformis (Fig. 39).
—— tuberculatus.

* This species, as observed by Messrs. Sharman and Newton, seems almost identical with forms noted as *Pleuromya crassa*. (See also List of Fossils at end of volume.)

Zones of AMMONITES OBTUSUS (Fig. 15), A. OXYNOTUS (Fig. 16), and A. RARICOSTATUS (Fig. 17).

A. bifer.
A. Birchii.
A. Bonnardi.
A. Brookei.
A. guibalianus.
A. planicosta (Dudressieri).*
A. sauzeanus.
A. stellaris.
Belemnites acutus.
—— elongatus.
Pleurotomaria anglica.
Avicula inæquivalvis.
Cardinia Listeri (Fig. 30).
—— —— var hybrida.
Gryphæa obliquata.
Hippopodium ponderosum (Fig. 29).
Waldheimia numismalis.
Extracrinus briareus (Fig. 40).
Pentacrinus basaltiformis (Fig. 39).
—— scalaris.
Montlivaltia rugosa.

Zones of AMMONITES ARMATUS (Fig. 18), A. JAMESONI (Fig. 19), and A. IBEX.†

Ammonites brevispina (Fig. 20).
—— Maugenesti.
—— planicosta.
—— subplanicosta.
—— Valdani.
—— trivialis.
Belemnites clavatus (Fig. 22).
—— elongatus.
Cryptænia expansa.
Arca Stricklandi.
Gryphæa obliquata.
Hippopodium ponderosum (Fig. 29).
Inoceramus (Crenatula) ventricosus.
Leda Galathea.
—— Zieteni.
Pinna folium.
Plicatula spinosa (Fig. 31).
Rhynchonella rimosa.
—— variabilis (Fig. 37).
Spiriferina verrucosa.
Waldheimia numismalis.
Pentacrinus scalaris.

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* *Ammonites planicosta* has occasionally been taken to mark a zone: the species extends up into the zone of *A. Jamesoni*.

† Lists of fossils from the zone of "*A. Jamesoni*," published by Tate, Quart. Journ. Geol. Soc., vol. xxvi. p. 400, and by T. Beesley, from Fenny Compton (see p. 160), include species from other zones.

FIG. 17.

FIG. 18.

FIG. 19.

FIG. 20.

FIG. 21.

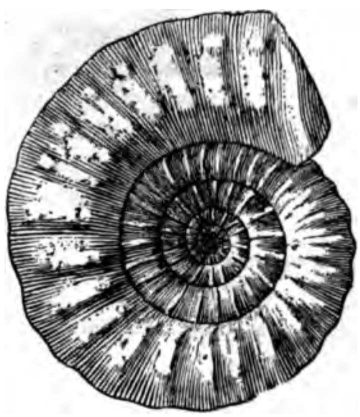


FIG. 22.

FIG. 17. *Ammonites raricostatus*, Ziet. $\frac{2}{3}$.
„ 18. „ *armatus*, Sow. $\frac{1}{2}$.
„ 19. „ *Jamesoni*, Sow. $\frac{1}{2}$
„ 20. „ *brevispina*, Sow. $\frac{2}{3}$
„ 21. „ *heterogenes*, Y. and B. $\frac{1}{2}$
„ 22. *Belemnites clavatus*, Blainv. $\frac{1}{2}$.

## LOWER LIAS CEPHALOPODA.

FIG. 23.

FIG. 24.

FIG. 25.

FIG. 26.

FIG. 23. *Ammonites striatus*, Rein. $\frac{1}{3}$
,, 24. ,, *Henleyi*, Sow. $\frac{1}{3}$.
,, 25. ,, *Davœi*, Sow. $\frac{1}{2}$
,, 26. ,, *capricornus*, Schloth. $\frac{1}{2}$.

Zones of AMMONITES HENLEYI (Fig. 24), and A. CAPRICORNUS (Fig. 26).

Ammonites Bechei.
—— Davœi (Fig. 25).
—— fimbriatus.
—— latæcosta.
—— Loscombei.
—— striatus (Fig. 23).
Belemnites apicicurvatus.
—— clavatus (Fig. 22).
—— elongatus.
—— longissimus.
—— penicillatus.
Pleurotomaria anglica (Fig. 27).
Arca Stricklandi.
Goniomya hybrida.
Hippopodium ponderosum (smooth form) (Fig. 29).
Inoceramus ventricosus.
Leda graphica.
Macrodon hettangiensis.
Modiola scalprum (Fig. 56, p. 190.)
Pholadomya ambigua.
Pleuromya costata (unioides).
Unicardium cardioides.
Montlivaltia Victoriæ.

LOWER LIAS MOLLUSCA.

FIG. 27.

FIG. 28.

FIG. 27. *Pleurotomaria anglica*, Sow. ⅔. Lower and Middle Lias.
,, 28. *Lima gigantea*, Sow. ½.

## Lower Lias Mollusca.

Fig. 29.

Fig. 30.

Fig. 31.

Fig. 32.

Fig. 33.

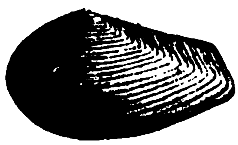


Fig. 35.

Fig. 34.

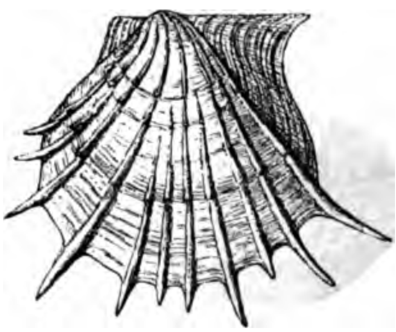


Fig. 29. *Hippopodium ponderosum*, Sow. $\frac{1}{2}$. Lower and Middle Lias.
„ 30. *Cardinia Listeri*, Sow. (nat. size).
„ 31. *Plicatula spinosa*, Sow. (nat. size). Lower and Middle Lias.
„ 32. *Modiola minima*, Sow. $1\frac{1}{3}$. Rhætic Beds and Lower Lias.
„ 33. *Pleuromya crowcombeia*, Moore (nat. size). Rhætic Beds and Lower Lias.
„ 34. *Avicula cygnipes*, Y. & B. $\frac{2}{3}$. Lower and Middle Lias.
„ 35. *Gryphæa arcuata*, Lam. (*G. incurva*, Sow.) $\frac{2}{3}$.

FIG. 36.

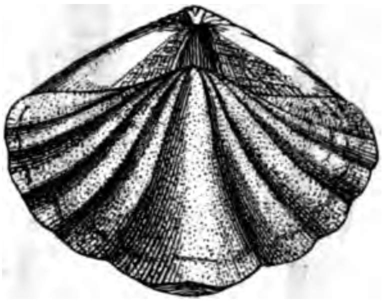


FIG. 37.

FIG. 38.

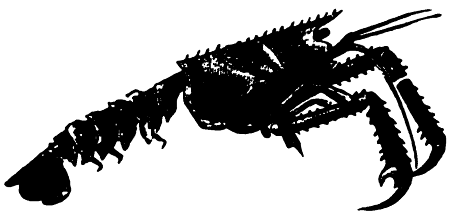


FIG. 39.

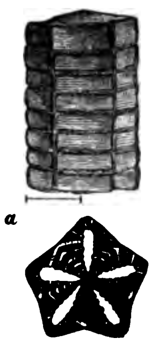



FIG. 40.


FIG. 36. *Spiriferina Walcotti*, Sow. (nat. size). Lower and Middle Lias.
" 37. *Rhynchonella variabilis*, Schloth. (nat. size). Lower and Middle Lias.
" 38. *Scapheus ancylochelis*, H. Woodw.
" 39. *Pentacrinus basaltiformis*, Miller. Lower and Middle Lias.
" 40. *Extracrinus briareus*, Miller.

FIG. 41.

*Section of the Cliffs from Pinhay Bay, near Lyme Regis, to Bridport Harbour.*

WEST. Horizontal Scale, about 4½ inches to a Mile. Vertical Scale, 800 feet to one Inch. EAST.

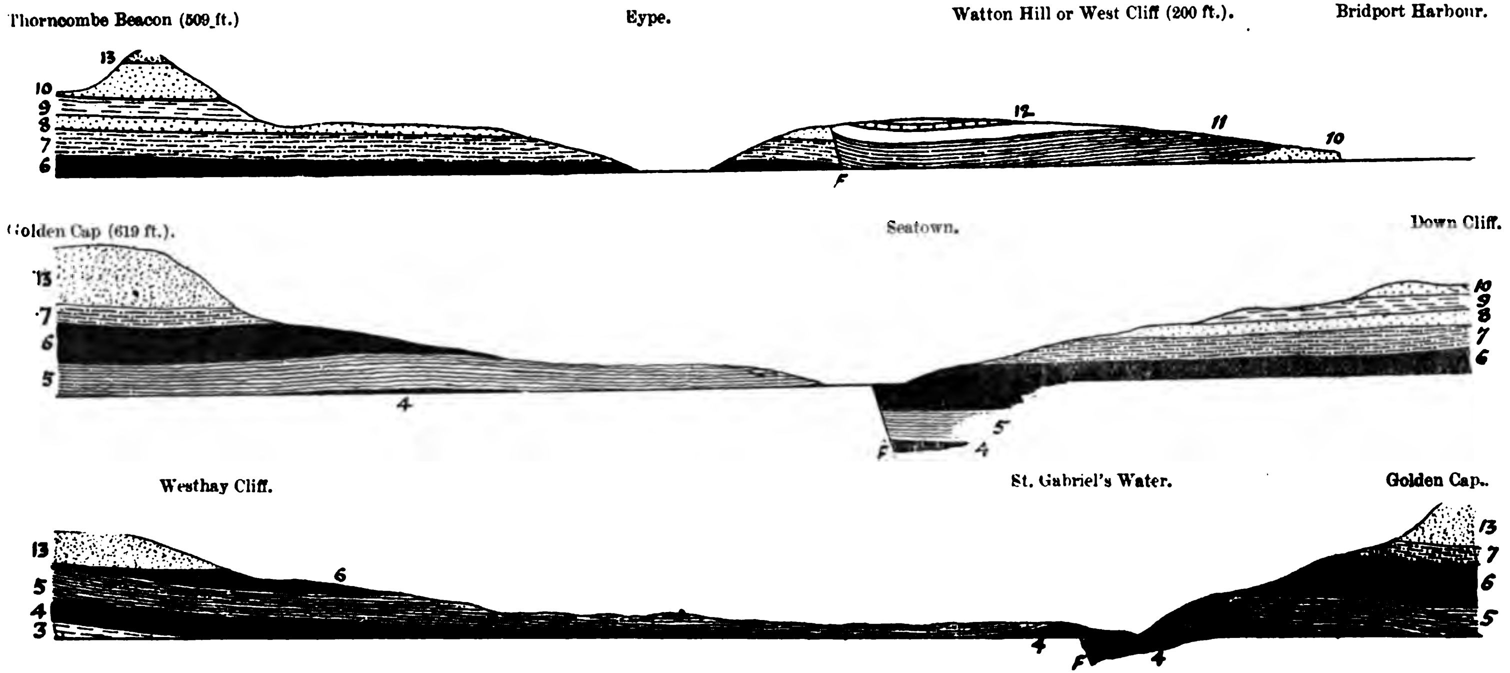
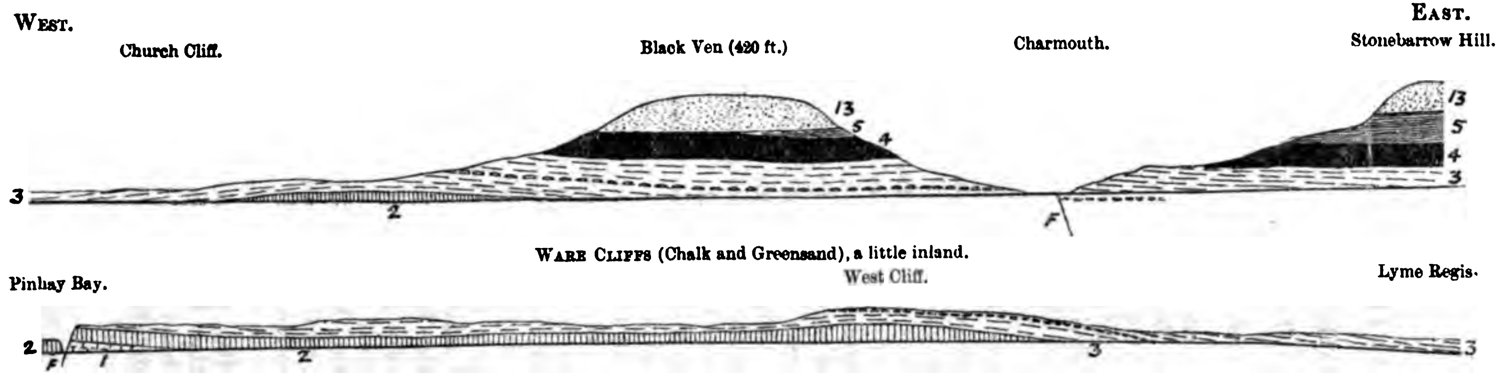


FIG. 41—*continued.*




F. Faults.
13. Chert gravel, Upper Greensand, and Gault.
12. Forest Marble. Shales with band of limestone. Fossil-bed (Bradford Clay) at base.
11. Fuller's Earth. Grey marl with bands of earthy limestone.
10. Midford Sands. Sands with bands and concretionary masses of calcareous sandstone — Zones of *Ammonites opalinus* and *A. jurensis*.
9. Upper Lias. Clays and sandy shales (passing into beds above). Thin limestone at base — Zones of *Ammonites jurensis*, *A. communis*, and *A. serpentinus*.

Middle Lias.
8. Marlstone (thin layer); Sands with concretionary masses of calcareous sandstone — Zone of *Ammonites spinatus*.
7. Laminated Beds. Sands, shales, and flaggy sandstone. Starfish-bed at base
6. Blue clays. Three Tiers (stone-beds) at base — Zone of *Ammonites margaritatus*.

Lower Lias.
5. Green Ammonite Beds. Clays with *Ammonites latæcosta* — Zone of *Ammonites capricornus*.
4. Belemnite Beds. Pale-grey marls, &c. — Zones of *Ammonites Jamesoni* and *A. armatus*.
3. Black Marl. Dark shales — Zones of *Ammonites raricostatus*, *A. oxynotus* and *A. obtusus*.
2. Blue Lias. Limestones and shales — Zones of *Ammonites Turneri*, *A. Bucklandi*, *A. angulatus*, and *A. planorbis*.

1. Rhætic Beds. White Lias.

# CHAPTER III.

## LOWER LIAS.

### LOCAL DETAILS.

*Dorsetshire Coast.*

In no other part of the country can the Lias, as a whole, be so well seen as on the coast between Axmouth and Bridport. The connection with the Keuper Marls, through the Rhætic Beds, can be studied near Culverhole Point and Charton Bay; while eastwards the several divisions can be traced in sequence until, near Bridport, we reach the Midford Sands that form the passage-beds between the Upper Lias and Inferior Oolite. From the base of the Lower Lias to the base of the Upper Lias all the beds can be examined and measured in detail, their continuity being only interrupted here and there by faults, the amount of whose displacement can be estimated with no great difficulty. Landslips, indeed, have masked the beds in many places, but not so as to interfere with the complete exposure of the series at one point or another. (See Fig. 42, p. 56.) With the Upper Lias the case is different. It is to be seen and its thickness can be estimated, but it is shown in an inaccessible portion of the cliffs below Thorncombe Beacon, and only its basement-bed can there be reached.

The highest point along this coast is Golden Cap, which rises to 619 feet, and owes its name to the sands of Upper Greensand age that form its summit; for these are "gilded" on a sunny day, and appear in marked contrast with the dark Liassic clays beneath. This is without doubt the grandest of the Lias cliffs in Dorsetshire. Its outlines are very varied, the precipices and slopes being scarred by deep channels and chines, separated by irregular peaks of Lias clay; while the thick bands of calcareous sandstone, known as the "Three Tiers," which constitute the base of the Middle Lias, form great buttresses along the lower portions of the cliffs.

Thorncombe Beacon, which rises to a height of 509 feet, presents the best view of the Middle and Upper Lias; while Black Ven (about 400 feet), and the adjoining cliffs near Lyme Regis, afford the best sections of the Lower Lias. (See Fig. 41.)

Notwithstanding the faults, which, having downthrows on the east, tend to carry the beds below the level sooner than would otherwise have been the case, there are opportunities of measuring the larger divisions at different points. Comparing results it will be found that the measurements of the

subdivisions differ to the extent of from 5 to 15 feet in various places. This may be due to original variations in the thickness of the strata, but it may also to some extent be attributed to a difference in pressure, the strata in some places being overlaid by thick and heavy accumulations, while in others they are at or near the surface.

The earliest geological descriptions of this coast-line were by De la Beche, who noted the leading lithological divisions in the strata and their organic remains, and gave an excellent pictorial diagram of the cliff-sections.*

Many years afterwards the Lower Lias beds were examined and described in detail by Dr. Wright, and subsequently the subdivisions of the Middle and Upper Lias were investigated very carefully by Mr. E. C. H. Day, who was assisted largely by Mr. R. Etheridge. These observers have furnished the greater part of our knowledge concerning the distribution of the organic remains, but to Dr. Wright especially we owe the adoption of that system of grouping the beds into Zones, which had been so ably marked out by Oppel. The help of local workers is however of the utmost importance to those who can spend but a few weeks in a district, and much of our knowledge of the horizons of fossils is due to the labours of the fossil-collectors, and especially to Samuel Clark and Robert Hunter of Charmouth.

De la Beche, in his account of the Lias, adopted the nomenclature of William Smith and Conybeare, so that his main divisions do not correspond with those now adopted, as will be seen from the accompanying table:—

| | | Modern Grouping. | Ft. |
|---|---|---|---|
| | | Upper Lias | 70 |
| Upper Lias Marls | | Middle Lias | 345 |
| | | Lower Lias | 485 |
| Lias Limestones | Blue Lias | | |
| | White Lias | Rhætic Beds. | |
| Lower Lias Marls | Black Shales | | |
| | Grey Marls | | |

The full thickness of the Lias is thus about 900 feet, and it is desirable to describe the beds as far as possible in detail, as nowhere else in our area have we such a connected series of exposures.†

* Trans. Geol. Soc., ser. 2, vol. i. pp. 40–47, and Plate VIII.; vol. ii. pp. 21–30, and Plate III.; and Report on the Geology of Cornwall, Devon, and West Somerset (Geol. Survey), 1839, pp. 222–235.

† My first acquaintance with the sections was made in 1873–74, when engaged, in conjunction with Mr. Clement Reid, in re-surveying portions of the district. In 1884 I examined the coast-section in detail, and constructed a horizontal section to show the relations of the several subdivisions. This was published in a condensed form in 1886. See Report on Coast-erosion, Rep. Brit. Assoc. for 1885, p. 424; Geology of England and Wales, Edit. 2, 1887, p. 252; and account of excursion to Lyme Regis., Proc. Geol. Assoc., vol. xi. p. xxvi. (Reprinted).

FIG. 42.

*The Landslip at Dowlands, between Lyme Regis and Axmouth.* (From a drawing by Sir A. Geikie, 1885.)

The Lower Lias is exposed in the cliffs between Culverhole Point and Seatown, near Golden Cap, where the strata admit of the following divisions:—

| | Ft. | Zones. |
|---|---|---|
| 4. "Green Ammonite Beds." Bluish-grey clays | 105 | *Ammonites capricornus* and *A. Henleyi*. |
| 3. "Belemnite Beds." Pale grey marls | 80 | (*A. Ibex*),* *A. Jamesoni*, and *A. armatus*. |
| 2. "Black Marl." Dark shales | 195 | *A. raricostatus*, *A. oxynotus*, and *A. obtusus*. |
| 1. "Blue Lias." Limestones and shales | 105 | *A. semicostatus* and *A. Turneri*, *A. Bucklandi*, *A. angulatus*, and *A. planorbis*. |
| | 485 | |

1. "*Blue Lias*."—This division comprises alternating bands of limestone and clay or marl, to which, as elsewhere, the term "Blue Lias" is confined.

The beds appear to the east of Culverhole Point, and probably extend higher up in the cliffs about as far west as Dowlands, but they are much tumbled and obscured by landslips. Proceeding eastwards, gentle undulations bring the strata to a higher level in Charton Bay, where the underlying White Lias and the beds down to the base of the Rhætic series may be observed.

It is not until Pinhay (or Pinney) Bay is reached that the beds are seen to advantage. A ravine and watercourse here coincide with a fault, that throws down the Lias limestones some 40 feet on the west (see Fig. 41), a dislocation depicted by De la Beche. On the east, the lowest beds of the Lias are seen resting on the White Lias, and in marked contrast as to colour. Now the upward succession can be traced, and each band of limestone can be examined. Before studying the beds in detail, it is however a good plan to obtain a general view of the cliffs from a boat at a short distance from the shore. In this way it will be seen that about 16 feet above the main mass of limestones, and separated from them by clays or shales, there is a conspicuous band of hard grey marl known as the Table Ledge. This band, increasing slightly in thickness, can be traced along these west cliffs as far as the Lime and Cement Works, beyond which the beds are concealed by the Esplanade; but it re-appears in the Church Cliffs, descending to the beach at the foot of Black Ven, where its easterly dip carries it out of sight. (See Fig. 41.) This band is taken as the top of the Blue Lias series. Partly owing to the curvature of the coast, the beds in the West Cliff present a gentle synclinal followed by an anticlinal structure. Moreover below the Esplanade the beds sink again, so that the Cobb is based on the surface of the main mass of stone-beds, which appear on the foreshore, and here the ledges stand out in graceful curves that mark the synclinal structure. Some of the ledges that occurred here, as elsewhere, have been broken up

* This species has not been recognized in this district.

and removed by the hand of man, and among them portions of the "Table-rock" were formerly exposed near the eastern jetty.*

Dr. Wright has spoken of Table Ledge as the same as the Broad Ledge, but the latter is certainly at a lower horizon, and is probably the "Grey Ledge" that forms the top of the main mass of Stone-beds. Broad Ledge is the name applied to a platform of rocks exposed at low tide at some distance from the eastern jetty, south-east of the Church Cliffs. At the base of these cliffs, the artificial removal of the ledges has largely aided the natural destruction of the cliffs, and the foreshore being full of muddy holes, affords a very treacherous route for the traveller.

The thickness of the main mass of stone-beds, may be reckoned at 70 feet on the eastern side of Pinhay Bay, but detailed measurements made at different points on the coast to Black Ven, indicate that the thickness increases to 80 or 85 feet. Taking the beds up to the Table Ledge we have a full thickness of about 105 feet.

It will be noticed from a general view of the beds that they may roughly be grouped as follows:—

| | Ft. | In. |
|---|---|---|
| E. Shales capped by the Hard Marl or Table Ledge - - | 19 | 0 |
| D. Limestones and clays (in about equal proportion) - - | 24 | 0 |
| C. Limestones with thin clay divisions - - - - | 23 | 0 |
| B. Limestones and clays (in about equal proportion) - - | 17 | 0 |
| A. Limestones with thin clay divisions - - - - | 22 | 0 |

Owing to the dip of the beds, the lower two divisions are exposed only in the cliffs immediately east of Pinhay Bay. They do not reappear further on in the West Cliffs, nor do they rise again in the Church Cliffs. The lowest zone in the Lias must thus be looked for as we pass eastwards from Pinhay Bay. Here, and indeed all along the coast to near Black Ven, the cliffs are mostly vertical, and they are more or less dangerous to those who walk along the beach, on account of the crumbling of the cliffs and the loose fragments of rock that occasionally fall. Attention must also be paid to the state of the tide, as the beds are otherwise inaccessible.

At the base of the Lower Lias there are thin laminated shales or paper-shales, that are frequently present at this horizon. Where exposed on the foreshore during spring-tides, the beds are seen to be crowded with spines of Echinoderms, whose tests also are sometimes preserved. Among the species Dr. Wright recognized *Cidaris Edwardsi*, *Pseudodiadema lobatum*, *Hemipedina Bechei*, and *H. Bowerbanki*. A similar bed occurs in the same position at Church Lawford, near Rugby.

The limestones above, yield *Ostrea liassica*, *Modiola minima*, *Arca Lycetti*, *Gervillia*, and *Pleuromya crowcombeia*. Some of these species I obtained in the beds above the White Lias at Charton Bay. *Ammonites planorbis* and *A. Johnstoni* have been found at Pinhay Bay, but as the beds are not worked for economic

* See G. Roberts, History and Antiquities of the Borough of Lyme Regis and Charmouth, 1834, pp. 211, &c.

purposes on this particular part of the coast, specimens are rarely obtained: they may however be found in the quarries at Uplyme. There is no evidence whereby the zone of *Ammonites planorbis* can be definitely marked off from the zones succeeding.* *Gryphæa arcuata* (*incurva*) and *Lima gigantea*, which are characteristic of the "Bucklandi-beds," occur about 7 feet above the White Lias, but the forms found so low down are usually much smaller than those met with above. The lower division (A) must however include all the beds representing the zone of *Ammonites planorbis*.

Continuing eastwards we traverse ledges formed by the successive bands of limestone. *Gryphæa arcuata* and *Lima gigantea* become more abundant. Some layers are crowded with *Rhynchonella calcicosta* (*R. variabilis* of Wright), and in others we find shoals of Pentacrinites. Here and there *Ammonites angulatus* may be observed. Further on we come to the cliffs where the stone is extensively worked for the Lime and Cement Works, and much of it (about 120 tons a week) is shipped away in the raw state. The stone is collected from the tumbled masses on the beach, and when these have been removed the stone in the cliffs is blasted. Each layer has its distinctive name, known to the workmen, and these names are recorded in the accompanying detailed section. The beds here are practically the same as those seen in the Church Cliffs, and the same names are applied to them. In the Church Cliffs the beds are somewhat disturbed by small faults.

The beds belong mainly to the zone of *Ammonites Bucklandi*, but include the upper portion of the zone of *A. angulatus*, the lower portion of which has been previously traversed. The succession of the zones is as well-marked as could be expected, albeit there is no reason to point to any particular layer to indicate a separating plane. *A. angulatus* and *A. Bucklandi* occur together at this locality.†

In these beds we may obtain fine specimens of *Lima gigantea* and *Ammonites Charmassei*; the latter, as remarked by Dr. Wright, is ribbed in youth, but quite smooth in old age. It occurs as high up as the "Best Bed." Large specimens of *A. Bucklandi* are common, and *Nautilus striatus* and *Pentacrinus basaltiformis* may usually be found. *Spiriferina pinguis* has also been recorded, and I have obtained *Ammonites bisulcatus* and *Rhynchonella calcicosta* at Charton Bay.

*Ammonites semicostatus* occurs near the top of the stone-beds at Lyme Regis, as well as in the Hard Marl or Table Ledge above; beds which have been grouped by Dr. Wright in the zone of *Ammonites Turneri*. The type of this latter species was obtained from the Drift of Norfolk, and named after Dawson Turner, of Yarmouth. Some doubt has been expressed whether

* Dr. Wright, Quart. Journ. Geol. Soc., vol. xvi. pp. 396, 397, considered that the *Am. planorbis* beds were represented by the White Lias, a mistake that arose from certain beds in the Lower Lias being locally termed "White Lias" by the quarrymen.

† See also R. F. Tomes, Quart. Journ. Geol. Soc., vol. xxxiv. p. 179.

the species has actually been obtained at Lyme Regis; but Dr. Wright records it from the Hard Marl, and from the underlying clays and shales down to the "Grey Ledge," and I have obtained specimens from the foreshore. *A. Bonnardi* is recognized by Messrs. Sharman and Newton from this locality, and this is a form closely approaching *A. Turneri.* Specimens of both species of Ammonites are frequently partly enveloped or replaced by iron-pyrites; and most of them have been found on the beach or among the fallen blocks near the northern end of the Church Cliffs. Specimens thus mineralized would not have come from the Hard Marl, but might occur in any of the shaly strata. A block of limestone purchased from Mrs. Dollin, of Lyme Regis, contains *A. Bonnardi* and *A. Turneri?* Dr. Wright records *A. Bonnardi* from the beds (above mentioned) which he groups in the zone of *A. Turneri;* but I have not found it *in situ.* It occurs also higher up in the series. Mr. Day, indeed, considered that *A. Brookei* was the local equivalent of *A. Turneri,* forms regarded by Dr. Wright as very closely allied; but *A. Brookei* occurs in a higher horizon, in the zone of *A. obtusus.* Under these circumstances it will be best to regard the upper portion of this Blue Lias series rather as the zone of *Ammonites semicostatus* than of *A. Turneri,* for the former species is found often in abundance on the same approximate horizon in other parts of England and has more generally been adopted as the zonal Ammonite.*

The Blue Lias series of Lyme Regis thus includes the zones of *Ammonites planorbis, A. angulatus, A. Bucklandi,* and *A. semicostatus;* an arrangement that fits in well with other parts of England, as it includes the main mass of the Lower Lias limestones, where these are well-developed.

The Hard Marl, and the West Rock, an iron-stained cementstone that occurs in West Cliff at a higher level in the clays above, are said to make a superfine cement when mixed together.

The following is a detailed account of the Blue Lias series of Lyme Regis, with the local names applied to the beds by the workmen:—†

| | | Ft. | In. |
|---|---|---|---|
| Division E. with 2 beds of marl and limestone: about 19 feet. Representing zone of *Ammonites semicostatus.* Seen in Church Cliffs, West Cliff, and Pinhay Bay. | Hard Marl or Table Ledge. ("Indurated Marl," of De la Beche.) Grey marl. *Ammonites semicostatus* [*A. Turneri*], *Avicula, inæquivalvis, Rhynchonella calcicosta* (= *variabilis* of Wright) - - - - - | 3 | 6 |
| | Saurian Bed. Shale. [*Ichthyosaurus communis, I. platyodon, Am. semicostatus, Rh. calcicosta*] - - - - - - | 12 | 0 |
| | Split Ledge or Fish Bed. Shaly limestone, breaking into pencil-like slabs. [*Am. Turneri, A. semicostatus*] - - - - - | 0 | 4 |
| | Marl and shale with limestone-nodules - - | 3 | 8 |

* Ussher, Geology of Lincoln (Mem. Geol. Survey, Sheet 83), p. 16.

† A detailed section was published by Dr. Wright, Quart. Journ. Geol. Soc., vol. xvi. pp. 401, &c. The species included in square brackets are given on his authority, but it is not possible to correlate all the particular beds he enumerates with those above noted.

| | | Ft. | In. |
|---|---|---|---|
| Division D. with about 9 beds of limestone: about 24 feet. Representing the zone of *Ammonites Bucklandi* (in part). Seen in Church Cliff, West Cliff, and Pinhay Bay. | GREY LEDGE.* Grey earthy limestone with fucoidal markings. *Am. Bucklandi, Lima gigantea* [*Lima antiquata, Rh. calcicosta*] - Shale. [*Plesiosaurus rostratus*] - - - | 3 | 6 |
| | GLASS BOTTLE. Irregular grey limestone. Large *Am. Bucklandi* on under surface. [*Lima gigantea, L. antiquata, Rh. calcicosta*] - Shale - - - - - - - TOP OR 1ST QUICK LEDGE. Even band of grey limestone - - - - - Marly shale - - - - - - VENTY BED. Even band of grey limestone, marly at base - - - - - | 3 | 0 |
| | Shale and marl with occasional nodules of limestone - - - - - - - | 5 | 9 |
| | BEST BED. Very even bed of limestone. Large *Lima gigantea, Am. Charmassei* - - - | 0 | 9 |
| | Shale - - - - - - - | 0 | 8 |
| | SECOND BED. Very even bed of limestone. *Nautilus, Pentacrinus* - - - - - | 1 | 3 |
| | Dark shales - - - - - - RATTLE. Impersistent limestone passing into marl - - - - - - - Dark shales with a few impersistent layers of limestone - - - - - | 5 | 0 |
| | MIDDLE OR 2ND QUICK LEDGE. Even band of grey limestone: well marked in cliff, and one of the highest beds that comes to the shore in ledges near Devonshire Point. *Pentacrinus* Shale (impersistent) - - - - - GUMPTION. Thin band of grey limestone - | 1 | 6 |
| | Grey marl and shale with "beef" (fibrous carbonate of lime), pyritic layers, and occasional nodules of limestone - - - - | 3 | 6 |
| Division C. with about 26 bands of limestone: about 23 feet. Representing the zone of *Ammonites Bucklandi* (in part) and the upper portion of the zone of *A. angulatus*. Seen in Church Cliff, West Cliff, and Pinhay Bay. | UNDER OR 3RD QUICK LEDGE. Grey shelly limestone. *Nautilus, Ostrea* - - - Shale with thin seams of "beef" - - TOP TAPE. Grey shelly limestone with lignite. *Am. Bucklandi, Pentacrinus, Scapheus ancylochelis* (Fig. 38, p. 51) described by Dr. H. Woodward from "Tape Ledge" - - Shale with lignite - - - - - | 3 | 3 |
| | UNDER OR 2ND TAPE. Grey limestone. *Gryphæa arcuata* abundant, *Am. Bucklandi* - - TOP COPPER. Dark limestone with iron-pyrites Dark shale. *Gry. arcuata, Rhynch. calcicosta* - MONGREL. Irregular grey limestone. *Rh. calcicosta* abundant - - - - Shale and shaly marl with impersistent mottled limestone, SKULL. *Gry. arcuata* - - | 4 | 6 |
| | SPECKETTY BED. Grey limestone, *Rh. calcicosta* - - - - - - - Dark shales. *G. arcuata* - - - - UPPER WHITE BED. Limestone, *G. arcuata, Lima* - - - - - - - SKULLS. Layers of irregular and impersistent limestone and clay. *Ammonites* - - IRON LEDGE. Grey limestone. *Rh. calcicosta.* This is the lowest bed work in the cliff west of Lyme Regis - - - - - Dark shale - - - - - - - UNDER COPPER. Grey limestone with "mundic" (iron-pyrites) - - - - | 6 | 6 |

* The "Grey Ledge" was misplaced in Dr. Wright's section.

| | | Ft. | In. |
|---|---|---|---|
| | Dark shales and grey limestones, very little hard rock - - - - - - - | 2 | 9 |
| | Under White Bed. Sparry limestone. *Lima gigantea*, *G. arcuata* - - - - -<br>Skulls. Limestones with very irregular surfaces, and very little shale. Large *Lima gigantea*. These are the lowest beds seen in Church Cliff - - - - - - | 3 | 6 |
| | Dark shales - - - - - -<br>Limestones and shales with Pig's Dirt or Soft Bed, and Brick Ledge. These are the lowest beds worked on the foreshore below West Cliff and Church Cliff - - - | 3 | 0 |
| Division B. with about 10 bands of limestone: 17 feet. Representing the zone of *Ammonites angulatus* (in part). Seen in Pinhay Bay. | Shale with bands and nodules of limestone. *G. arcuata* - - - - - - | 5 | 0 |
| | Grey limestone - - - - - - | 0 | 9 |
| | Dark shale and shaly marl with two thin bands of limestone - - - - - - | 6 | 9 |
| | Dark shales with five bands of even and irregular limestone - - - - - - | 5 | 3 |
| Division A. with about 26 bands of limestone: 22 to 24 feet. Representing the zone of *Ammonites planorbis* and perhaps a part of that of *A. angulatus*. Seen in Pinhay Bay. | Grey shelly limestone - - - - - | 1 | 0 |
| | Shale - - - - - - - - | 1 | 6 |
| | Shales with five beds of even-bedded limestone. *Lima gigantea* abundant - - - - | 3 | 0 |
| | Shales with five irregular bands of limestone. *Pholadomya*, *Ammonites* - - - - | 3 | 3 |
| | Compact limestone with marly base, weathering white, and forming a conspicuous ledge near Pinney Bay - - - - - - | 1 | 3 |
| | Shale - - - - - - - - | 1 | 6 |
| | Limestone with large *Ostrea*, *G. arcuata*, *Lima gigantea* - - - - - -<br>Shales with 3 bands of limestone - -<br>Limestone with *Modiola*, *Ostrea liassica*, *G. arcuata* - - - - - - | 6 | 0 |
| | Shale with 4 bands of limestone, *Ostrea*, &c. - | 2 | 0 |
| | Shale and 4 bands of shelly limestone, *Ostrea liassica* - - - - - - -<br>Irregular bed of limestone, disturbed in places, the lower part ferruginous and shelly. *Ostrea liassica* | 3 | 6 |
| | Brown laminated shales with thin films of limestone - - - - - - - - | 1 | 0 |
| Rhætic Beds. | White Lias. | | |

2. *Black Marl.*—The dark shales that overlie the "Table Ledge" are locally known as the "Black Marl," and the appearance of these beds well accounts for the name of Black Ven. In this cliff the entire division can be studied. The summit of the hill is capped by Chert gravel, Upper Greensand, and Gault. The base of the Gault is marked by a thin pebbly layer or grit, but the formation itself, as remarked by the Rev. W. Downes, is pervious to such an extent that springs are thrown out by the Lias clay beneath.* It is well moreover to bear in mind that the fossils of the Gault and Lower Lias are sometimes commingled on the slopes.

* Quart. Journ. Geol. Soc., vol. xli. p. 23.

The Lias of Black Ven is exposed in three terraces that form the lower portions of the cliff beneath the Cretaceous rocks. The uppermost of these is formed for the most part of pale grey marls, known as the "Belemnite Beds (to be described further on). The terraces below are formed by the much darker shales, clays, and marls, which will now be noted in detail.

Near the top of the lowest terrace there is a prominent band of nodular limestone or cement-stone inclined towards the Charmouth valley and terminating in the low cliff near the Coast Guard Station. It is slightly faulted at one point under Black Ven with a downthrow of 5 or 10 feet on the west. (See Fig. 41, p. 53.) It is not however shown in the cliffs east of Charmouth, as a more important fault traversing the valley, throws down the beds about 50 feet on the east. This fault was noticed by Mr. Day.

The band of cement-stones or "Firestone Nodules"* is known as the *Birchii* Bed," from the occurrence of *Ammonites Birchii.* The specimens are known to collectors as the "Tortoise Ammonites," and also as "White Ammonites" from the white calc-spar that often fills the chambers of the shells. In the same nodules many small and juvenile Ammonites occur. The band was most accessible in the western part of Black Ven towards the Church Cliffs; it sometimes includes two layers of cement-stone nodules.

Specimens of limestone, crowded with small ammonites (*A. obtusus, A. planicosta,* and *A. Smithi*) occur at a higher horizon beneath the Pentacrinite Bed; these are often to be picked up on the beach, and they present resemblances to the famous Ammonite Marble of Marston Magna, which is on the same geological horizon.

Nodular limestone with *Ammonites semicostatus* is said to occur in the shales beneath the "*Birchii* Bed"; and this is not inconsistent with evidence obtained elsewhere, where this species ranges above the strata allotted to it as a zone.

Fine specimens of *Ammonites obtusus* occur here and there in the clays and nodular limestones between the Table Ledge and the Coin Stone Bed; this division was regarded by Dr. Wright as the zone of *A. obtusus;* here also, and more especially in the shaly marls above the *Birchii* Bed, occurs *A. Brookei.* Specimens enveloped in iron-pyrites are not uncommon. *A. Bonnardi* has also been recorded from this series.

Above the shaly marl with *A. Brookei,* there are two layers known as the "Two Cement Beds," which are seen in the lower part of the middle clay-terrace of Black Ven; and the higher band, which is the more conspicuous one, re-appears in the lower part of the cliff east of Charmouth. Tumbled masses of these beds have been used for paving-stone or pitching.

Not far below the Coin Stone Bed is the layer known as the Pentacrinite Bed, which has yielded many fine specimens of

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* I have been informed that some of the nodules were formerly used for fires, as fire-balls.

*Extracrinus briareus*, mostly coated or replaced by iron-pyrites. (See p. 70.)

The Coin Stone Bed is the name applied to the upper portion of a band of large cement-stones, that forms two and sometimes three layers. They occur in the top of the middle clay-terrace of Black Ven, and form a noticeable band, about 40 feet beneath the pale-grey Belemnite Beds, in the cliffs of Stonebarrow to the east of Charmouth. A large cut and polished Septarian-limestone with *Ammonites stellaris* (now in the Museum at Jermyn Street), was obtained by Robert Hunter from one of these huge cement-stones. Dr. Wright observes that the nodules often contain very large specimens of *A. obtusus* and *A. Brookei*, the veins of spar in the rock intersecting and distorting the fossils.*

Immediately above these beds we enter the zone of *Ammonites oxynotus*, specimens of which are prevalent in the dark pyritic shales and clays about 10 feet above the Coin Stone Bed. The variety of this species known as *A. lymensis*, and *A. densinodus* likewise occur.

Still higher in the same set of shales, *A. armatus* and *A. raricostatus* occur, but there is nothing to indicate any plane of demarcation between the zones. I obtained one specimen of *A. raricostatus* from the beds on this horizon east of Charmouth, but it extends upwards into the Belemnite Beds above.

These higher beds of shale are however more impregnated with iron-pyrites than is the case lower down, although this mineral is more or less abundant throughout the Black Marl Series. It was however from this upper portion that much pyrites was at one time obtained, during the winter months, for the manufacture of sulphuric acid; and there is a band in the shales known as the "Metal Bed."

The series now under notice extends to the base of the upper terrace under Black Ven, where two or three bands of limestone occur at the junction with the Belemnite Beds. These bands were mostly obscured in Black Ven by talus (in 1884), but were shown in the cliffs of Stonebarrow on the east.

The Black Marl thus includes the zones of *Ammonites obtusus*, *A. oxynotus*, and *A. raricostatus*, which here and elsewhere may be conveniently linked together. Here the beds yielding *A. obtusus* form by far the greater portion of the series, the zonal Ammonite (according to Dr. Wright) being found at various horizons between the Hard Marl and the Coin Stone Bed: but the associated species are not many. Dr. Wright records *Am. Birchii*, *A. Brookei*, *A. stellaris*, *A. planicosta*, *A. sauzeanus*, and *A. semicostatus*.†

Some of the cement-stones near Charmouth have been employed for making cement, and remains of a disused cement-mill still stand near the sea-shore.

* Lias Ammonites (Palæontograph. Soc.), p. 50.
† Lias Ammonites, Pal. Soc., pp. 50, 51.

Section of the "Black Marl" beds of Black Ven:—

| | | Ft. | In. |
|---|---|---|---|
| | Belemnite Beds. | | |
| Zone of *Ammonites raricostatus* about 15 ft. | Grey earthy limestone - - - | 0 | 9 |
| | Micaceous and marly shale with nodules of limestone. Belemnites abundant. [Compressed metallic specimens of *Am. raricostatus*, found by Mr. Day] - | 0 | 6 |
| | Hard grey limestone - - - - | 0 | 4 |
| | Dark shaly marl with *A. armatus*: including METAL BED with much iron-pyrites - - - - - - | 10 0 to 15 | 0 |
| Zone of *A. oxynotus* about 15 ft. | Dark shaly marl with *A. oxynotus*, found 10 feet above Coin Stone - - | 15 | 0 |
| Zone of *A. obtusus* about 170 ft. | COIN STONE BED (Corn Stone Ledge of Dr. Wright). Cement-stone bed, that forms a prominent band in Stonebarrow Cliff. Fish-remains - - - -<br>Dark shales with nodules of limestone -<br>Ferruginous and marly cement-stone. Large specimens of *Am. stellaris* in nodules; also *A. Brookei* [Wright] - | 10 | 0 |
| | Dark shaly marls with PENTACRINITE BED, yielding *Extracrinus briareus*; and, below, impersistent layers of limestone (like Ammonite Marble) with many small Ammonites, *A. obtusus*, &c.<br>Dark slightly micaceous and calcareous paper-shales with flattened Ammonites | 25 | 0 |
| | Band of irregular indurated marl - | 1 | 3 |
| | Dark shaly marl and shale with nodules of limestone - - - - - | 8 | 0 |
| | UPPER CEMENT BED. Hard iron-stained Cement-stone, an irregular and conspicuous band - - - | 1 | 3 |
| | Nodular and impersistent limestones with Saurian remains - - - -<br>Shaly marls - - - - - | 9 | 0 |
| | Thin band of limestone - - -<br>Marls - - - - - - | 6 | 0 |
| | LOWER CEMENT BED. Hard irregular iron-stained marly limestone or cement-stone: seen near base of cliff East of Charmouth. This, and the bed a few feet above, are known as the "Two Cement Beds" - - - | 1 | 0 |
| | Shaly marls, yielding fine specimens of *Ammonites Brookei* - - - | 30 0 to 40 | 0 |
| | FIRESTONE NODULES OR BIRCHII BED. Hard irregular and nodular limestone or Cement-stone, with "beef" above and below. It forms one or two beds with iron-stained joints. *Am. Birchii* and clusters of small Ammonites - | 1 | 6 |
| | Dark Shales with band of thin shaly limestone, and occasional nodules of limestone - - - - - | 10 | 0 |
| | Lenticular band of grey limestone, with "beef" - - - - -<br>Dark shales, with thin band of limestone in places - - - - -<br>Interrupted band of limestone with "beef." | 15 | 0 |

| | Ft. | In. |
|---|---|---|
| Dark shales and paper-shales, slightly calcareous and micaceous, with indurated bands and seams of "beef." [Saurian remains] | 25 | 0 |
| Marly cement-stone bed. Marly shales with iron-pyrites, and thin conspicuous layer in the West Cliff known as the BLACK BEAR | 25 | 0 |
| Hard Marl or Table Ledge. | | |

3. *Belemnite Beds.* — This division, as before mentioned, occupies the higher portions of the clay-cliffs at Black Ven, forming the third terrace. It appears as a well-marked light-grey band here, and again in Stonebarrow, where the easterly dip brings it nearer and nearer to the sea-level (see Fig. 41, p. 53). It disappears, however, abruptly, west of St. Gabriel's Water, Golden Cap, owing to a fault with a downthrow of about 40 feet on the east.

The mass of the beds is by no means rich in fossils, for although *Belemnites Milleri* and *B. compressus* may be found dispersed through the lower and central portions of the marls, few other fossils are to be seen. Now and again an Ammonite, poorly preserved, may be obtained, but I succeeded only in finding specimens of *A. raricostatus* and *A. semicostatus*, which thus range above the regions assigned as their appropriate zones.

Lenticular masses of lignite, approaching jet in character, occur in places; and I noticed one mass at a depth of 3 feet 6 inches below the Belemnite Stone under Golden Cap. The central portion of this division is formed by a band of harder pale grey marls, thicker and more conspicuous in some places than in others.

To the upper portion of this series most interest attaches, for there occurs a band of dark shaly marls rich in fossils, covered by a thin layer of pale marly limestone, known as the "Belemnite Stone," and also very fossiliferous.

Black Ven is not the most convenient place to examine these beds, for the platform at their foot is exceedingly wet and boggy, springs being thrown out at the junction with the denser clays and shales below. Good sections are exposed in some of the gullies in Stonebarrow Cliff and particularly to the east of Breakneck Gully, and here their fossil treasures may most readily be obtained.*

The finest exposures of the beds however are on the foreshore below Golden Cap, for the strata (which were thrown down by a fault a little further west), re-appear owing to a gentle anticlinal at the base of Golden Cap, and are usually well-exposed rather to the east of the loftiest portion of the cliffs, where again there is evidence of slight faulting. The foreshore along which the beds are shown at low tide, is rather to the west of this exposure, and there a grand exhibition of Belemnites and other fossils is to

* In his section, Trans. Geol. Soc. ser. 2. vol. i. Plate viii., De la Beche marked Stonebarrow Cliff as "Shorne Cliff," but the latter is the name applied to the western slope of Golden Cap. See also Report on the Geology of Cornwall, &c. p. 227.

be seen, some in the Belemnite Stone, others in still greater profusion in different layers of the dark shaly marls beneath. The long pencil-like forms of *B. longissimus* are conspicuous, but difficult to extract, while *B. elongatus*, *B. clavatus*, and *B. pollex* are not uncommon. A large number of species have been identified, and these include also *B. apicicurvatus*, *B. Bucklandi*, *B. compressus*, *B. junceus*, *B. Milleri*, *B. nitidus*, *B. penicillatus*, *B. striolatus*, and *B. vulgaris*.* Among the Ammonites *A. fimbriatus* and *A. striatus* may be found in the Belemnite Stone.

The dark shaly marl especially, yields a number of small pyritic Ammonites, which may be found in the Stonebarrow cliffs, and which are collected for sale at Black Ven. These are cut and polished for brooches, the species being *Ammonites subplanicosta*, and *A. planicosta* (*Dudressieri*). Species of *Amberleya* (*Eucyclus*) also occur together with *Waldheimia numismalis*, *Pentacrinus basaltiformis*, &c.

Mr. Day has given a general list of fossils from the Belemnite Beds, which he regarded as the commencement of the Middle Lias. He however admitted that there was no real line of separation between the Lower and Middle Lias.† (See p. 33.)

With regard to the palæontological horizons in this division, there can be no doubt that the zones of *Ammonites armatus*, *A. Ibex*, and *A. Jamesoni* are represented: but we find no evidence here, and none elsewhere to separate these zones. At Fenny Compton we find the same general association of forms in beds grouped under the name "Jamesoni Beds" by Mr. Beesley, but this name was used mainly for convenience as the fossils of the zone of *A. armatus* could not be separated. So far as I know the zone of *A. Ibex* is nowhere distinctly to be recognized in this country.

Oppel doubtfully included the region of *Ammonites armatus* in this set of beds, and it was recognized also by Dr. Wright. Fine specimens of *A. armatus*, with large spines, have been obtained from the neighbourhood of Lyme Regis; but as they usually come from fallen blocks the precise horizon cannot always be stated. They are mostly found at Black Ven, and some, at any rate, come from beds grouped with the zone of *A. raricostatus*.

Oppel also recognized the zone of *A. Jamesoni*, with *A. brevispina*, *Waldheimia numismalis*, &c., evidently in the dark shaly beds below the Belemnite Stone; and this zone was also placed in the Belemnite Beds by Dr. Wright, who records *A. Jamesoni* from "Charmouth." I obtained no examples either of this species, or of *A. Ibex* from Dorsetshire. Oppel considered that the zone of *A. Ibex* containing *A. Loscombei* and *A. Henleyi* occurred below his "*Davœi*-bett," but this assemblage belongs rather to a higher stage, being a part of the Green Ammonite Beds, to be shortly described. I am not aware that *A. Ibex* has ever been obtained in Dorsetshire. Dr. Wright mentions that he had seen no example of the species from the district, and while refraining

* J. Phillips, Monograph on Belemnites (Palæontograph. Soc.).

† Quart. Journ. Geol. Soc., vol. xix. p. 290; see also Geol. and Nat. Hist. Repertory, vol. i. p. 193.

from a precise indication of the zone, he states that he recognized several fossils belonging to it, " as, for example, *A. Valdani* and *A. Maugenesti*, in greyish-coloured clay beneath a bed with *A. Davœi*."*

From these remarks it may be inferred that the main lithological divisions, which we are able to make in the Lower Lias of Dorsetshire, do not correspond at all precisely with the ranges of the zonal species of Ammonites: an inference, the truth of which is confirmed by a study of the Lias in other parts of the country. We have in fact, on the Dorsetshire coast, as elsewhere, an inosculation of the zones which prevents our marking rigid limits for them.

The following are the details of the Belemnite Beds:—

| | | Ft. | In. |
|---|---|---|---|
| Zones of *Ammonites Ibex*, *A. Jamesoni*, and *A. armatus*. about 80 feet. | Belemnite Stone. Hard pale-grey uneven marly limestone - - - | 0 6 to 0 | 8 |
| | Dark shaly marls with much iron-pyrites, and pyritic fossils; with nodules and impersistent masses of hard grey limestone, within two feet of the Belemnite Stone - - - | 6 | 0 |
| | Pale grey marls - - - - - - | 35 | 0 |
| | Hard marly limestone and hard pale and dark grey marls, forming ledges in the gullies of Stonebarrow Cliff over which springs fall. Thickness variable - - - - - | 6 | 0 |
| | Grey shaly and micaceous marls - - | 30 | 0 |
| | Marly limestones and shales - - - - | 1 | 0 |
| | Shales - - - - - - - | 1 | 0 |

Grey earthy limestone (top of Black Marl series).

4. *Green Ammonite Beds.*—Above the Belemnite Beds comes a series of bluish-grey micaceous marly clays, with occasional indurated bands, nodules of hard grey limestone, and ferruginous layers, altogether about 105 feet thick. Towards the lower part of the series the limestone-nodules are most abundant and frequently contain specimens of *Ammonites latœcosta*, Sow. These when cut and polished are sold under the name of " Green Ammonites " because the spar filling the chambers is often of a green colour. The same Ammonite is abundant in the marly beds, but usually in a fragmentary state. Hence the name " Green Ammonite Beds," adopted by Mr. Day, and which may be used as a general term for the marls between the Belemnite Stone and the Three Tiers.†

Traces of these beds first appear in Black Ven, although on account of the slips and the difficulty of getting at the strata, they cannot be well examined. Proceeding eastwards they occur above the Belemnite Beds in Stonebarrow Cliff, and although traces of the Tiers are found in places, showing that the entire thickness of the beds is represented, only the lower portion is there well exposed. The beds however are clearly shown beneath the Three Tiers in Golden Cap. Commencing east of St. Gabriel's Water, they are exposed along the base of the cliffs, above the Belemnite Beds (which appear here and there), as far as

* Lias Ammonites, pp. 83–89.

† Day, Quart. Journ. Geol. Soc., vol. xix. p. 278.

the Coast-guard station at Seatown, where about 70 feet of the beds, including the upper portion, may be seen. These beds do not appear east of Seatown, being let down on that side of the valley, below the sea-level, by a fault (noticed by Mr. Day), which has a downthrow of from 190 to 200 feet. Under the coast-guard station the beds are much disturbed and even contorted, features partly due to the fault and partly to landslips.

Oppel grouped part of this series as the "*Davöi-bett*," characterized by *Ammonites Davæi*, *A. capricornus*, *A. fimbriatus*, and *A. Henleyi*. Dr. Wright, who has also spoken of the beds as the zone of *A. Davæi*, included them in the zone of *A. Henleyi*, but unfortunately extended the zone above the Three Tiers, as high as the Starfish-bed, whereby he included a series of marls that are characterized by *A. margaritatus*.*

*Ammonites latæcosta* is unquestionably the most characteristic fossil, and this species curiously enough has been regarded by Dr. Wright as the middle-age condition of *A. Henleyi*; while Oppel speaks of it as a Capricorn-Ammonite,† and mentions his finding 25 specimens of *A. capricornus* at Charmouth. Some specimens of *A. latæcosta* which I have collected, are regarded by Mr. E. T. Newton as very near to *A. capricornus*, and that species has been recorded from the Dorsetshire coast by Mr. Etheridge, as well as by Oppel as mentioned above.

There is therefore good reason to classify the beds with the zones of *A. Henleyi* and *A. capricornus*, although the "Henleyi Ammonites" appear in the upper part of the preceding division.

Among the species which I have collected are *A. Bechei*, *A. Henleyi*, *A. striatus*, *A. Davæi*, and *A. Loscombei*, forms which are also characteristic of the same horizon at Chipping Norton in Oxfordshire. *A. Loscombei* appears to be most abundant in the upper part of the Green Ammonite Beds,‡ but specimens occur in the same block with *A. latæcosta*.

The details of the Green Ammonite Beds are as follows:—

| | | Ft. | In. |
|---|---|---|---|
| | Three Tiers (base of Middle Lias). | | |
| Zones of *Ammonites capricornus* and *A. Henleyi*. about 105 feet. | Sandy and ferruginous clay; Bluish-grey micaceous marly clay with ironstone nodules and iron-stained limestone-nodules | 12 | 0 |
| | Micaceous flaggy bed, sandy calcareous and ferruginous; seen on the east side of Golden Cap | 1 | 0 |
| | Bluish-grey micaceous marly clay | 20 | 0 |
| | Ferruginous band. *Ammonites Loscombei*; Bluish-grey micaceous marly clay | 18 | 0 |
| | Occasional bands of indurated marl or limestone; Bluish-grey marly clays with nodules of hard grey limestone and ferruginous bands. *Ammonites latæcosta*, *A. striatus*, *Inoceramus*. | 54 | 0 |

The above thicknesses are estimates taken from measurements at different places, where the thickness varies a good deal: indeed on the eastern side of Golden Cap a thickness of 125 feet was measured, from the base of the lowest Tier to the top of the Belemnite Stone.

* Wright, Lias Ammonites, pp. 89, 420.
† Juraformation, pp. 155, 157.
‡ See also Day, Quart. Journ. Geol. Soc., vol. xix. p. 291.

Concerning the Saurians for which Lyme Regis is noted, most of the remains have been found in the Blue Lias series of the West Cliff and of the Church Cliffs, and in the overlying dark shales and cement-stones of Black Ven. The species are thus for the most part preserved at higher horizons than is the case with the noted locality of Street in Somersetshire. Remains of *Ichthyosaurus* (see Figs. 2, 4, and 6, pp. 37–39) from the Blue Lias, are found generally in layers between the stone-beds, and a fine specimen of *Plesiosaurus* was obtained from these beds (zone of *Am. Bucklandi*) by Mr. Day.*

Although for at least 100 years the fossils of Lyme Regis and its neighbourhood have been collected for sale, it was not until 1811 that Mary Anning, the most noted of the early fossil-collectors, obtained the first specimen of *Ichthyosaurus* which was brought into scientific notice. This was originally described by Sir Everard Home, and in 1819 he gave the name *Proteo-saurus*; but in the previous year Koenig had applied the name *Ichthyosaurus,* and that name, largely owing to the labours of Conybeare, became known and adopted.

In 1821 the same collector obtained remains of another Saurian, described by Conybeare under the name *Plesiosaurus* (see Figs. 3 and 7, pp. 37, 39); and in 1828 she procured (for the first time in this country) the Pterodactyl, of which the species described by Buckland is now known as *Dimorphodon macronyx.*

Another noteworthy form is the *Scelidosaurus Harrisoni,* a Dinosaur obtained from Charmouth by James Harrison. This like many of the other fine Saurians, was obtained piece-meal and at intervals.

Many species of Fishes have been obtained from the Lower Lias of Lyme Regis, and to a large extent through the personal exertions of the Earl of Enniskillen and Sir Philip Egerton. Little however, is known of the special horizons of these fossils, although many, such as *Æchmodus, Chondrosteus, Dapedius, Lepidotus,* and *Pachycormus* are assigned to the zone of *Ammonites obtusus.* Other genera such as *Acrodus, Hybodus,* and *Pholidophorus,* together with *Dapedius* have been obtained from the stone-beds below.† (See Figs. 8–11, pp. 40, 41.)

The Coprolites originally described by Buckland were found in the same set of beds. (See Fig. 2, p. 37.) There are few records of any vertebrate remains from the Belemnite Beds and higher stages of the Lower Lias of Dorsetshire.

Among Crustacea there are species of *Eryon, Æger, Glyphea,* and *Scapheus.* No Insects are known from the locality. Of Echinoderms, certain forms have been noticed in the lowest beds, while portions of *Pentacrinus* are found more or less plentifully at various horizons. The most striking form is the "Briarean Encrinite" *Extracrinus briareus* (Fig. 40, p. 51), which being

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* Geol. Mag. 1864, p. 47.

† See lists by Egerton in De la Beche's Report, p. 225; Wright, Lias Ammonites (Palæontograph. Soc.), p. 61.

often found associated with lignite, was thought by Buckland to have attached itself in large groups to masses of floating wood.*

Of the Mollusca, attention has been drawn to the prevalent forms, but it may be mentioned that many of the species figured by Sowerby were obtained from Lyme Regis and the neighbourhood. Among these were *A. Bechei* (named after De la Beche), *A. Birchii* (after Col. Birch, a great frequenter of Lyme), *A. Brookei* (after H. J. Brooke), *A. Davæi* (after Sir H. Davy), *A. Henleyi* (after H. H. Henley, the Lord of the Manor), and *A. Loscombei* (after C. W. Loscombe), together with *A. fimbriatus*, *A. latæcosta*, *A. stellaris*, and *A. striatus*.

Among the Belemnites it may be mentioned that *Belemnosepia* (*Geoteuthis*) was described by Buckland in 1836. Ten years previously he had obtained specimens exhibiting remnants of fossil ink, samples of which were submitted to Sir Francis Chantrey, who had a drawing prepared with the material.† The sepia was pronounced to be of excellent quality. Remains of *Xiphoteuthis* have also been obtained, and Prof. Huxley has described two species of Belemnites—*B. elongatus* and *B. paxillosus*—with the ink-bags preserved. The latter species was obtained from the zone of *Ammonites obtusus*.‡

Gasteropoda are by no means abundant at Lyme Regis, but they are more plentiful east of Charmouth. No Polyzoa have been recorded, and Corals are extremely rare Some few plant-remains have been found; these belong to the genera *Pachyphyllum* (*Araucarites*) and *Otozamites* (*Otopteris*). In the hall of the Museum of Practical Geology, there is exhibited a trunk of *Pachyphyllum* (*Araucarites*) *peregrinum*, nearly 13 feet in length; and preserved in the rock with it is a specimen of *Ammonites armatus*.

Lyell figured, from the Lower Lias of Lyme Regis, a specimen of lignite that contained the impression of an Ammonite.§

Two examples of Cycadean stems have also been recorded from the "Lias" of Lyme Regis, under the names of *Yatesia gracilis* and *Mantellia* (*Cycadeoidea*) *pygmæa*.||

The conclusions to be drawn from the beds seen in the cliffs of Lyme Regis and Charmouth are that we find in upward succession, beds yielding *Ammonites planorbis*, *A. angulatus*, *A. Bucklandi*, *A. semicostatus* and *A. Turneri*, *A. obtusus*, *A. oxynotus*, *A. raricostatus*, *A. armatus*, *A. Henleyi*, and *A capricornus*, (represented chiefly by *A. latæcosta*). We find a blending of the zones of *A. angulatus* and *A. Bucklandi*, of *A. semicostatus* and *A. obtusus*, of *A. raricostatus* and *A. armatus*.

Following the beds across country we find the same general succession maintained, and similar evidences of the association of zonal species which link the strata intimately together, without

* Bridgewater Treatise, 1836, p. 437.
† Bridgewater Treatise, 1836, p. 305; Proc. Geol., Soc. vol. i. p. 97.
‡ Monograph on the Belemnitidæ (Geol. Survey), 1864.
§ Elements of Geology, 1838, p. 399.
|| Carruthers, Trans. Linn. Soc., vol. xxvi., pp. 689, 703.

interfering with the sequence of the species. Inland we have to depend on comparatively limited sections, sometimes revealing evidence of a single zone, in other cases of a blending of two zones. It must be remembered however that to obtain good specimens *in situ* is often a difficult task: the best examples, whether from brickyards or quarries, being most frequently obtained from workmen or from the spoil-heaps, so that the precise position of each fossil cannot always be determined.

*Inland sections, Dorsetshire and Devonshire to Membury and Chard.*

Proceeding inland from the Dorsetshire coast, the Lower Lias limestones may be traced at Uplyme and Axminster, and thence by Membury to the higher part of the Yart Valley near Buckland St. Mary; but their outcrop is much obscured by the overstepping of the Upper Greensand and Chalk, which form the dominant features in this area.

The quarries at Uplyme are situated a short distance north-west of the church; and in the one known as Fowler's quarry, about 25 feet of Lower Lias limestone and clay may be seen resting on the White Lias.

In this neighbourhood, also near Axminster, and again near Street in Somersetshire, there is sometimes a difficulty in readily determining the junction between the Lower Lias and White Lias. Among the Lower Lias limestones there are beds of pale marly limestone and compact limestone that much resemble beds of White Lias, and locally the term "White Lias" is applied by the quarrymen to them, while the name "White Rock" is given to the true White Lias. To this fact we may attribute Dr. Wright's grouping of the White Lias in the zone of *Ammonites planorbis*, a grouping that was strongly opposed by Charles Moore,* and has been shown by subsequent observations to have been based on a mistaken identification of the beds.

It will be noticed however at Uplyme, as well as at Pinhay Bay, that the White Lias, which yields *Modiola minima*, *Ostrea liassica*, *Cardium rhæticum*, and *Pecten valoniensis*, contains here and there throughout its mass, nodules or pebbles of compact limestone, that stand out conspicuously on the weathered surfaces. These included portions of limestone are sometimes more compact than the matrix, but in no case do they differ from beds represented in the White Lias. They appear to be due to some contemporaneous destruction of the beds, and when I accompanied Sir A. Geikie to the Dorsetshire coast in 1885, he suggested that the calcareous mud may, during the accumulation of the strata, have been from time to time exposed to the sun's rays, so that films of mud might have curled-up, and these, if subsequently rolled by an incoming tide, would be shaped into the lumps which form so conspicuous

* Quart. Journ. Geol. Soc., vol. xvii. p. 483; Wright, *Ibid.*, vol. xvi. p. 396; and Lias Ammonites (Pal. Soc.), p. 21; also H. B. W., Proc. Geol. Assoc., vol. xi. p. xxx.

a feature in these beds. As already noticed (p. 9), evidences of contemporaneous erosion are not uncommon in other strata, in the Inferior Oolite, &c.

At Uplyme the White Lias is directly overlaid by about 10 inches of brown laminated marly clay as at Pinhay Bay; above comes a band of sandy limestone, and then blue and pale grey limestones and clays, the lower portion of which represents the zone of *Ammonites planorbis*. This species has been met with, together with *A. Johnstoni*, and slabs covered with *Ostrea liassica* are noticeable. Spines of *Cidaris* and *Hemipedina* were observed by Dr. Wright.* *Gryphæa arcuata* occurs within a few feet of the White Lias, and we find also *Avicula, Modiola*, and *Waldheimia perforata*. *Lima gigantea* appears in the higher beds, which no doubt represent portions of the zone of *Am. angulatus*.

The Lower Lias limestones are well shown near Axminster, in quarries by the London and South-Western Railway north of Weycroft. The beds have been worked for a long period, and their fossils early attracted the attention of Buckland, who was born at Axminster in 1784. He has given a description of the beds with the local quarrymen's names; and it is noteworthy that the terms Burr (or Bur), Anvil, Size, and Firestone are employed at this locality, and also at Uplyme. The names are applied without respect to relative horizon, but to the character and uses of the beds. The Burrs furnish good building-stone, so do the Anvils, which form "a bed of irregular anvil-shaped blocks." The Firestone, is a "white building-stone, used also for forming the arch-work of lime pits." The Red Size (described as "white lias inclining to grey") is used for paving and building.†

At Greatwood, north-west of Weycroft, the term Firestone is applied to a cherty limestone, and here, as well as in a quarry north-west of Longlea, Mr. C. Reid found thin beds of sandstone intercalated among the thick-bedded earthy limestones. Near Buckland St. Mary he noticed that the Lower Lias occasionally contains lenticular masses of impure lignite, such as are seen near Charmouth.

We have no records near Axminster of the full thickness of the Blue Lias series, but the quarries do not show more than 15 or 20 feet of stone-beds. Judging from the evidence obtainable, there is reason for believing that the stone-beds of Lyme Regis rapidly diminish in thickness towards the north; a large part of the zone of *Ammonites Bucklandi* being represented by clays with subordinate bands of stone, near Axminster and along the eastern borders of the vale of Taunton, as we know to be the case further north along the Polden Hills. *Modiola minima* occurs in the bottom beds of rubbly limestone above the "White Rock" (White Lias) at Tolhay; there the beds above consist of dark blue clays and shales with interrupted layers of limestone, whose

* Lias Ammonites (Palæontograph. Soc.), p. 21; see also Quart. Journ. Geol. Soc., vol. xvi. p. 397.

† Buckland, Trans. Geol. Soc., Ser. 2. vol. i., p. 98; Reliquiæ Diluvianæ, Ed. 2, 1824, p. 242.

separation in some places appears to be due to the effects of disturbance. Mr. Reid observed that near Sarte and at Chapplecroft the Sun Bed on top of the "White Rock," exhibited an eroded surface with borings of Mollusca. Remains of *Otozamites* have been obtained from the Lower Lias near Membury and Axminster.

Again, proceeding inland from the Dorsetshire coast, we find the Lower Lias clays developed over a considerable area in the higher part of the Char valley—a tract known as the Vale of Marshwood. An occasional brickyard affords some clue to the character of the sub-strata, but there are few sections and no marked features to guide us in fixing the boundary between the Lower and Middle Lias. It should, moreover, be borne in mind that on the coast there are several faults, while the Oolitic district to the east is very much dislocated. So that no doubt many disturbances affect the clayey beds in the Vale of Marshwood, although we have no evidence, such as would be furnished by the interruption and displacement of hard strata or recognizable bands of stone, to indicate the position of faults. Further north, near Axminster and White Staunton, where the limestones outcrop, the Lower Lias is shown to be much faulted and broken; some of these disturbances affect also the Cretaceous strata, while others appear only to have influenced the older beds.

The Lower Lias clays occur over much of the country east of Weycroft, near Hawkchurch and Chard junction in the Axe Valley, and in the valley by Chardstock and Wambrook—the limestones being brought up in one or two places by faults.* North-east of Chard the clays are again exposed, but in this area, as in so many others, we have no sections to indicate the palæontological horizons, and to help in fixing the boundary-line with the Middle Lias.

Mr. C. Reid ascertained that at the Ship Inn, near the reservoir at Chard, a well was sunk 22 feet to black shale, which burnt, and had a very offensive smell. Doubtless it was this shale, which many years ago led to a fruitless trial for coal, when about 3,000*l.* was uselessly expended. Mr. Reid was informed that a shaft was sunk 100 feet, and a boring was carried to a further depth of 300 feet in the "Lias," but no particulars are known.† The reservoir is based on a platform of limestone, but this may be only a band in the Lower Lias clays.

### *Vale of Taunton to Ilminster.*

In the escarpment bordering the Vale of Taunton, the Lower Lias reappears from beneath the covering of Cretaceous rocks, and is not again so concealed throughout its course.

The lower portion of the Blue Lias series is exposed in many places along this escarpment; and quarries have been noted by

* See De la Beche, Report on the Geology of Cornwall, &c., p. 290.
† De la Beche, Report, p. 515; Geol. East Somerset (Geol. Survey), p. 48.

Mr. Ussher north of Holmin Clavil, near Feltham, Hayne, and on Pickeridge Hill. The stone has been long quarried south of Thurlbeer where blue limestones (Thurlbeer Stone) and shales have been opened up to a depth of 16 feet. Resting on the White Lias, here and at Belmont, are two thin layers of limestone, known as the "Hat and Cap." (See p. 78.)

An excellent section of the Lower Lias and Rhætic Beds was exposed in the railway-cutting at Hatch Beauchamp. The beds are faulted, and the Lower Lias limestones and clays are bent into an anticlinal in one portion of the cutting. Charles Moore assigned a thickness of about 60 feet to these beds, but the confusion into which the higher beds are thrown renders this estimate doubtful. From the abundance of *Ostrea liassica* throughout the series, it is evident that the beds belong to the zone of *Ammonites planorbis*. Moore notes this fossil, also *O. intusstriata* (in the bottom-bed), and *Monotis* (*Avicula*) *decussata* (? = *M. fallax*) in a bed of blue marl, about 10 feet above the White Lias, while *Pholadomya ambigua* occurred some way up, and *Pecten pollux* at the top of the series.*

Other quarries exposing 20 to 25 feet of the lowest beds of the Lias and the White Lias, may be seen near Beer Crocombe, Curry Mallet, Fivehead and Curry Rivell. The Lias beds exposed in all these quarries, belong to the zone of *Ammonites planorbis*, which includes at its base the Saurian zone of Mr. Moore, and the Ostrea-beds.† Limestones and blue clays were observed by Mr. Ussher on Barrington and Abbey Hills and near Curland; and these beds probably belong to the zone of *Am. Bucklandi.*

A quarry at Curry Rivell showed the following section:—

| | | Ft. | In. |
|---|---|---|---|
| Lower Lias. Zone of *Am. planorbis*. | Even beds of blue limestone and slaty marls or shales - - - - - - | 10 | 0 |
| | Whitish marly limestones and clays with *Modiola minima* and *Ostrea liassica* - | 6 | 0 |
| Rhætic Beds. | Sun bed, with irregular corrugated surface, in places penetrated by small perforations refilled with limestone of similar character - - - - - - | 0 | 6 |
| | White Lias limestone, *Modiola minima* - | 10 | 0 |

The perforations in the Sun bed (first noticed by Messrs. Bristow and Etheridge), were probably the burrows of Annelides in the soft calcareous mud of the Rhætic period, and therefore contemporaneous with the sediment now consolidated.‡

The clays of the Lower Lias extend northwards from the neighbourhood of Chard, over Ashill and Neroche Forests, south of Hatch Beauchamp, and thence towards Ilminster, Isle Abbots, and Hambridge, north of Puckington. The beds are covered here and

* Quart. Journ. Geol. Soc., vol. xxiii. p. 469.
† See Moore, Quart. Journ. Geol. Soc., vol. xvii. pp. 485, 490.
‡ J. H. Blake and H. B. Woodward, Geol. Mag. 1872, p. 196; Memoir on the Geology of East Somerset, &c. p. 73. See also Vertical Sections, No. 5, Sheet 47, by H. W. Bristow & R. Etheridge.

there by patches of gravel, or of cherty detritus from the Greensand hills. At Broadway, north-west of Ilminster, a well (according to Mr. Reid) was sunk 90 feet in clay, and at Ashill the "Lower Lias marls" were proved to a depth of 80 feet.

A cutting by the railway east of Horton near Ilminster, showed the following section:—

| | | | Ft. | In. |
|---|---|---|---|---|
| | Gravel | about | 4 | 0 |
| Lower Lias | Stiff blue clay with nodular and septarian limestones; *Belemnites* and *Cardinia* | 12 0 to | 15 | 0 |
| | Sandy limestones | about | 4 | 0 |

The evidence for marking out zones in the Lias in this area is thus extremely meagre. As indicative of the zone of *Ammonites capricornus*, it may be mentioned that in the Bath Museum there is a specimen of *A. Davæi* from the neighbourhood of Ilminster.

At Hambridge Mills, a boring made in 1873, was carried to a depth of a little over 300 feet, as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Lower Lias | Dark blue clay | 121 | 1 |
| | Blue lias rock | 0 | 11 |
| | Clay | 41 | 3 |
| | Clay and two bands of rock | 4 | 9 |
| | Clay | 21 | 10 |
| | Clay and rock, alternating | 119 | 2 |
| | | 309 | 0 |

*Vale of Ilchester and the Polden Hills.*

Passing on to the Vale of Ilchester and the Polden Hills, we still find the main limestones to belong to the zone of *Ammonites planorbis*. (See Fig. 66, p. 206, and Fig. 84, p. 263.) The general divisions are as follows:—

| | | | Feet. |
|---|---|---|---|
| Lower Lias | 4. Blue and brown clays | about | 200 |
| | 3. Clays with bands of limestone | " | 80 |
| | 2. Even-bedded grey argillaceous and compact blue limestones and shales, and fissile or "slaty" marls | | 20 to 40 |
| | 1. Rubbly white or pale grey earthy limestones and marls (locally); resting on the White Lias | | 6 to 10 |

The lower beds (1) contain *Ostrea liassica* and *Modiola minima*, and are seen in some road-cuttings near Somerton, and near Walton windmill, Street. They form passage-beds between the White Lias and Lower Lias, rendering it in some places perplexing to fix a line of demarcation.* In the even-bedded limestones (2), which are largely quarried, *Ostrea liassica* is abundant (in the lower beds), and *Pleuromya crowcombeia*, small specimens of *Lima gigantea*, and *Ammonites planorbis*, may generally be found. Saurian remains also occur. Some of the more compact

* See Geology of East Somerset, &c., pp. 103, &c.

bands of blue lias resemble the Sun bed or Jew stone* that occurs on the top of the White Lias.

The stone-beds are mainly confined to the area of the river Yeo, and west of the Fosse Way. Numerous quarries indicate their presence in the outliers north of Langport, near Long Sutton, Somerton, Kingsdon, Charlton Adam, King Weston, and Keinton Mandefield.† Among the more important are the quarries at Highbrooks, between Long Sutton and Kingsdon, and those at King Weston. There we find even-bedded and persistent bands of limestone (4 or 5 inches thick) and clays. Slabs of stone 6 × 10 feet in size are obtained, for paving-purposes; blocks are shaped for building-material; and some beds are used for road-metal. Perhaps the best sections are exposed near Keinton Mandefield, and the following account of the Stipstone quarry (named after the field in which it is situated) gives the names in local use:—

| | | Ft. | In. |
|---|---|---|---|
| | Posts. Limestones and clays (used for road-metal) | 3 | 0 |
| | Thin yellow. Limestone in three beds | 0 | 9 |
| | Shale | 0 | 9 |
| | Thick yellow. Limestones with *Ammonites planorbis* | 0 | 6 |
| | Shale | 1 | 4 |
| | Thin corner or Corn stone. Limestone with *Lima gigantea* | 0 | 6 |
| | Shale | 0 | 2 |
| | Thick corner. Limestone | 0 | 7 |
| | Thick white. Shelly limestone | 0 | 7 |
| | Thin white. Limestone | 0 | 3 |
| | Cream. Limestone (poor bed) | 0 | 6 |
| Lower Lias. Zone of *Am. planorbis*. | Red liver. Shelly limestone | 0 | 4 |
| | Thin black. Limestone (used for outdoor paving) | 0 | 6 |
| | Thick black. Limestone (used for outdoor paving) | 0 | 5 |
| | Thin cover. Limestone (used for paving) | 0 | 3 |
| | Thick cover. Limestone (used for paving) | 0 | 5 |
| | Clog. Limestone (used for building) | 0 | 7 |
| | Blue paviour. Limestone (used for paving) | 0 | 5 |
| | Heath stone. Limestone with *Ichthyosaurus* (used for curbs) | 0 | 5 |
| | Thin firestone. Limestone (used for curbs) | 0 | 3 |
| | Thick firestone. Grey limestone (used for curbs) | 1 | 2 |
| | (About 6 feet down to White Lias, with no good stone.) | | |

The "Thin Corner" and beds below, are all used for making lime for building and agricultural purposes. Many of the limestones are used for building-purposes, and some for troughs, steps, &c. The beds are often spoken of as "sizes," and they lie very close together with but thin partings of shale.

Immediately north of Queen Camel, a fault has upraised the White Lias, together with the overlying limestones of the Lower

* This is sometimes spelt Dew stone; *see* remarks on *Dhu* stone, p. 296.

† A section at Pisbury, east of Langport, was noted by Moore, Quart. Journ. Geol. Soc., vol. xvii. p. 91; see also Wright, *Ibid.*, vol. xvi. p. 391; Dawkins, *Ibid.*, vol. xx. p. 404, and Geol. Mag., 1864, p. 258.

Lias; and the beds are largely worked all along the ridge known as Camel Hill. Here the mass of the stone-beds belongs to the zone of *Ammonites planorbis*. An interesting section was exposed along the Great Western railway, and this was described in great detail by Charles Moore. The higher beds are now much obscured, but they include the zones of *Ammonites angulatus*, and *A. Bucklandi*, and probably portions of overlying beds. We find here, as elsewhere along the exposed tracts of Lias north of Lyme Regis, that the zone of *Ammonites Bucklandi* is for the most part represented by clay with comparatively few bands of limestone. Moore's account of the Queen Camel section may be summarized as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Zones of *Am. Bucklandi* and *A. angulatus*. | Thick beds of marl, with bands of limestone | 60 | 0 |
| | Alternations of marl and limestone; the marl preponderating - - - - | 48 | 6 |
| | Blue clay with *Ammonites angulatus* - | 4 | 0 |
| | Alternations of limestone and clay - - | 5 | 2 |
| Zone of *Am. planorbis*. | Limestone with *Am. planorbis* and *Gryphæa arcuata* - - - - - - | 0 | 4 |
| | Alternations of limestone and marl or clay, yielding - - - - - - | 97 | 0 |
| | Am. Johnstoni. | | |
| | —— planorbis. | | |
| | Nautilus. | | |
| | Astarte. | | |
| | Cardinia. | | |
| | Gryphæa arcuata. | | |
| | Lima duplicata. | | |
| | —— Hermanni. | | |
| | Modiola minima. | | |
| | Monotis (Avicula). | | |
| | Myacites. | | |
| | Ostrea liassica. | | |
| | ——— multicostata (arietis). | | |
| | Pecten sublævis. | | |
| | Unicardium cardioides. | | |
| | Pentacrinites. | | |
| | Echini. | | |
| | Ostracoda. | | |
| | Foraminifera. | | |
| | Saurian and Ostrea Beds. Alternations of limestone ("firestone," &c.) and marl - | 5 | 5 |
| | Am. planorbis. | | |
| | Modiola minima. | | |
| | Monotis (Avicula). | | |
| | Lima. | | |
| | Ostrea liassica. | | |
| | Cidaris Edwardsi. | | |
| | Insect and Crustacean Beds. Alternations of more or less laminated marl and limestone* - - - - - - | 4 | 9 |
| | Lepidotus. | | |
| | Modiola minima. | | |
| | Eryon wilmcotensis. | | |
| | Insects. | | |
| Rhætic Beds. | White Lias. | | |
| | | 225 | 2 |

* One band, here and elsewhere in the district to the west, is called the "Hat and Cap," because the stone flakes off when quarried, in the form of a hat or cap.

Moore's measurements thus give a thickness of 107 ft. 6 in. for the basement-beds of the Lower Lias, yielding *Ammonites planorbis*: a thickness elsewhere equalled at Rugby and near Carlisle. The evidence in this district, if not quite satisfactory, shows that these beds at any rate increase greatly in thickness from their main outcrop on the west and north-west. It is interesting moreover to note the occurrence of the Insect and Crustacean Beds, which so closely resemble those of Wilmcote and other parts of Warwickshire and adjoining tracts.

Some of the bands of limestone (16 to 18 feet above the White Lias) are much jointed, so as to shatter when struck with the hammer, like certain beds in the Lower Lias of Aberthaw; similar beds are seen along the Polden Hills.

Among the fossils collected at Queen Camel by Mr. J. Rhodes, were *Hippopodium* (cast), *Pholadomya*, *Rhynchonella*, and *Waldheimia perforata*. The occurrence of *Hippopodium* at so low an horizon in this part of the country is noteworthy.

Approaching the Mendip Hills we find the general line of outcrop much modified. In the Polden Hills the strike is W.N.W., and the beds outcrop towards the south. (See Fig. 84, p. 263.) Northwards they occupy a synclinal at Glastonbury, Meare, and below Brent Knoll, rising again near the Mendip Hills, although not without evidence of faulting.

In 1860 Dr. Wright published a section of Mr. Cree's quarry at Street, observing that he had compared it with the sections afforded by the quarries of Messrs. Seymour, Underwood, and Talbot in the same parish, and found that the variations in all these sections were so inconsiderable, that any one might be said to represent the others, both as regards the sequence of the beds and the fossils they contain. That this is the case may be seen by comparing the section noted by Dr. Wright with that noted by myself 25 years later:—

| Mr. Cree's Quarry, Street. Dr. T. Wright, 1860.* | Ft. In. | Mr. Joseph Seymour's Quarry, Overleigh, Street, 1885. Total depth, about 20 feet. | Ft. In. |
|---|---|---|---|
| 1. Light-coloured marly clay. TOP BED. Saurian bones, *Ammonites planorbis* - - - - | 3 0 | Thin grey limestone, much jointed. Brown clay - - - - | 2 0 |
| 2. Light-coloured limestone, *A. planorbis* - - - - | 0 9 | Pale-bluish limestone. YELLOW BED, occasionally used for road-metal and paving - - - | 0 8 |
| 3. Yellowish laminated shale, *Ichthyosaurus intermedius*, *A. planorbis*, *Lima punctata*, *Isastræa* (*latimæandroidea*) - - | 3 0 | Laminated shaly clay - - | 3 0 |
| 4. Light-coloured shaly limestone, *A. planorbis* - - - - | 0 4 | Limestone. TOP ROCK - -<br>Shale - - - - -<br>Limestone - - - - | 0 9 |
| 5. Hard grey limestone. BUILDING STONE. *A. planorbis*, *Lima punctata*, *L. gigantea* - - | 0 7 | | |
| 6. Dark-grey shale, *A. planorbis*. spines of *Cidaris* - - - | 0 3 | | |
| 7. Dark-grey limestone, CORN-SIZE BUILDING-STONE. Spines of *Cidaris*, bones of *Ichthyosaurus tenuirostris* - - - | 0 6 | Hard blue limestone. CORN SIZE, used for building - - - | 0 11 |

* Quart. Journ. Geol. Soc. vol. xvi. p. 390; Wright, Lias Ammonites (Palæontograph Soc.), p. 16; and T. Mellard Reade, Proc. Liverpool Geol. Soc., vol. iii. p. 99. See also Section at Pym Quarry, Street, by Messrs. Bristow and Etheridge, where the local names of beds, agreeing in the main with those above noted, are given, Vertical Sections, Sheet 47, No. 2; and Section of Cree's Quarry, Street, by R. F. Tomes, Quart. Journ. Geol. Soc., vol. xxxiv., p. 183.

| Mr. Cree's Quarry, Street. Dr. T. Wright, 1860. | Ft. In. | Mr. Joseph Seymour's Quarry, Overleigh, Street, 1885. Total depth, about 20 feet. | Ft. In. |
|---|---|---|---|
| 8. Dark laminated shale, *Ostrea liassica* - - - - | 0 4 | Marly shale - - - - - | 1 6 |
| 9. Dark-grey limestone, FIVE-INCH BUILDING-STONE. *O. liassica* - | 0 5 | Blue limestone. BUNCH BACK - | |
| 10. Dark shale. *O. liassica* - - | 0 3 | Shale - - - - - - | |
| 11. Dark-grey limestone. SIX-INCH BUILDING-STONE. *Cardinia crassiuscula*, *Lima punctata*, *O. liassica* - - - - | 0 6 | Blue limestone. CLAY BAT - | |
| | | Limestone. WHIT or WHITE STONE RID - - - - - | 0 7 |
| 12. Dark shale - - - - - | 0 6 | Dark shale - - - - - | 0 3 |
| 13. Hard greyish limestone, consisting of two four-inch beds. WHITE STONE. Best paving-bed. Fossils rare; *O. liassica*, *Modiola minima* - - - - - | 0 8 | Limestone, ferruginous, THICK WHIT or WHITE - - - - - | 0 6 |
| | | Do do. THIN WHIT - | 0 3 |
| 14. Hard dark marl. SAURIAN BED. Jaws of Saurians and Fishes. *Ichthyosaurus intermedius*, *Plesiosaurus Hawkinsi* - - | 0 9 | Limestone. CLIFT, used for floorings. [This passes into Shale, CREAM SHALE in Mr. Z. Seymour's Quarry.] | 0 6 |
| 15. Fine-grained greyish limestone. CREAM BED. Fine-grained paving-stone. *Ostrea*, *Modiola* - | 0 3 | Irregular limestone. CREAM - [A bed of clay CREAM SHELL CLAY intervenes in Mr. Seymour's Pit.] | 0 |
| 16. Brownish limestone. RED LIVER. Paving-stone. Few fossils - | 0 4 | Irregular Limestone. RED LIVER | 0 3 |
| 17. Dark-coloured limestone. BLACK STONE. Used for large paving-slabs, some of them 10 ft. by 5 ft. *Modiola minima*, *Ostrea liassica*, *Myacites* (*Pleuromya*), *Rhynchonella calcicosta* (*variabilis*) - - - - - | 0 4 | Do. do. BLACK STONE | 0 4 |
| 18. Dark-blue shale, *Ostrea liassica*, *Modiola minima* - - - | 0 2 | Shale - - - - - - | 0 3 |
| 19. Hard greyish limestone. SIX-INCH BUILDING-STONE. *Modiola minima*, *Ostrea liassica* - - | 0 6 | Limestone, solid and sound. SIX-INCH BED, used for curbs - - | 0 6 |
| 20. Soft bluish shale - - - - | 0 2 | Shale - - - - - | 0 5 |
| 21. Greyish-blue limestone. FOUR-INCH BUILDING-STONE. Fossils as in No. 19 - - - - | 0 4 | Limestone. LIVET, or LIBBETS - | 0 4 |
| 22. Dark-grey laminated shale. *Ichthyosaurus intermedius*, *I. tenuirostris* - - - - | 0 4 | Shale. [This is a shaly limestone, BLUE CLOG SHALE in Mr. Z. Seymour's Quarry.] | 0 3 |
| 23. Hard blue limestone. BLUE CLOG, or ONE-FOOT BUILDING-STONE, used for steps. *Ostrea*, *Modiola*, *Rhynchonella* - - - - | 1 0 | Limestone. BLUE CLOG, used for steps, buildings, &c., sometimes used for columns, and chimney-pieces, takes a good polish. | 0 11 |
| 24. Grey laminated shale. Saurians abundant. *Ichthyosaurus intermedius*, *I. tenuirostris*, *Pholidophorus* - - - - - | 1 3 | Shale. *Ichthyosaurus communis*. [This is a limestone GREY CLOG SHELL, in Mr. Z. Seymour's Quarry.] | 0 6 |
| 25. Greyish limestone. GREY CLOG. A valuable building-stone, used for steps, troughs, &c. *Modiola minima* - - - - - | 1 0 | Limestone. GREY CLOG, building-stone. | 0 8 |
| 26. Dark shale - - - - - | 0 2 | | |
| 27. Thin-bedded limestone. THREE-INCH BLUE BED. Fish-remains, *M. minima*, *Otozamites* (*Otopteris acuminatus* - - | 0 3 | Limestone. TOP BLUE - - [This occurs in two SIZES, 6 in., known as THIN BLUE, in Mr. Z. Seymour's Quarry.] | 0 3 |
| 28. Thick blue limestone - - | 0 5 | Limestone. THICK BLUE, used for paving. | 0 4 |
| 29. Hard fine-grained limestone. FIRE-STONE - - - - - | 0 4 | Limestone. FIRE BED, used for paving. | 0 6 |
| 30. Hard grey fine-grained limestone. *Plesiosaurus Etheridgei* (= *P. Hawkinsi*) (in Museum of Practical Geology) - - - - | 0 4 | Shale - - - - - | 0 2 |
| | | Limestone. BOTTOM BLUE, used for paving. | 0 5 |
| 31. Hard grey limestone, forming the bottom bed. FIRESTONE BOTTOM BED. *Plesiosaurus Hawkinsi* - | 1 0 | Limestone. BOTTOM FIRE - - [A bed of shale 5 in. NEW FOUND OUT RID., intervenes in Mr. Z. Seymour's Quarry.] | 0 7 |
| | | Limestone. NEW FOUND OUT, used for paving. [Fish, Cycads, Rain drops.]* | 0 4 |
| | 20 0 | | 18 0 |

* Noticed by T. Mellard Reade.

At Mr. Zachariah Seymour's Quarry at Street, the thickness of the beds measured, was 17 feet 11 inches from the Yellow Stone to the New Found Out, the depth of the quarry being about 19 feet. The details of the beds are almost identical with those noted above. From this quarry a specimen of Blue Clog, polished, was presented to the Museum of Practical Geology, by Mr. Seymour. The New Found Out is here 8 inches in thickness.

At Street many fine examples of *Ichthyosaurus* and *Plesiosaurus* have been obtained, and Thomas Hawkins, who resided at Sharpham Park, was furnished with much of the material for his illustrated work on the "Great Sea Dragons."

That the beds have proved so rich in Saurian-remains, is no doubt partly due to the extensive workings for stone, but it is partly due to the energy of local observers.

In addition to the species mentioned, *Plesiosaurus* (*Thaumatosaurus*) *megacephalus* and *P. macrocephalus* have been obtained in the neighbourhood;* and a few years ago Mr. Alfred Gillett, of Overleigh, procured a very perfect specimen of *Ichthyosaurus tenuirostris*, now in the British Museum, and lately described and figured.† Mr. Gillett has also obtained a number of Fish-remains, including species of *Amblyurus*, *Dapedius*, *Leptolepis*, and *Pholidophorus*. Among other fossils I obtained specimens of *Arca*, *Astarte*, *Cardinia*, *Cardium*, *Gryphæa arcuata* (small), *Lima*, *Pleuromya*, *Waldheimia*, and *Thecosmilia*.

With regard to Corals, both *Heterastræa* (*Isastræa*) *latimæandroidea* (= *I. Murchisoni* of Wright) and *H.* (*Septastræa*) *Haimei* have been recorded; the occurrence of the latter species has been considered erroneous;‡ but Dr. Wright states that he extracted it from the clay at Street, *in situ*.§

Evidence of the Zone of *Ammonites angulatus* has been obtained in the northern portion of the village of Street. Excavations lately made (1891) at Mead's Batch, have opened up beds of clay with bands of limestone, from which the following fossils have been obtained by Mr. Gillett and Dr. G. J. Hinde:—*Ammonites angulatus*, *A. Johnstoni*, hooklets of *Belemnites*, *Gryphæa arcuata* (small), *Gresslya galathea*, *Unicardium cardioides*, *Rhynchonella calcicosta*, and *Waldheimia perforata*.

The Lower Lias limestones, and the Rhætic Beds have been well exposed in the cutting of the Great Western railway at Dunball, near Puriton, and in the adjoining Cement and Lime Works belonging to Messrs. John Board & Co. The quarry shows the following beds:—

* See Huxley, Quart. Journ. Geol. Soc. vol. xvi. p. 291.

† R. Lydekker, Geol. Mag., 1891, p. 289.

‡ Tomes, Quart. Journ. Geol. Soc., vol. xxxiv. p. 183; Hinde, *Ibid.*, vol. xliv. p. 224; and Duncan, *Ibid.*, vol. xxiii. p. 18; Supp. Foss. Corals, Pal. Soc., Part iv. p. 8.

§ Proc. Cotteswold Club, vol. iv. p. 147.

| | | Ft. | In. |
|---|---|---|---|
| Lower Lias | Rubble and clay | 0 | 10 |
| | TOP LIAS. Limestone | 0 | 10 |
| | Shale | 1 | 0 |
| | SECOND LIAS. Limestone | 0 | 9 |
| | Shale | 0 | 9 |
| | TWO FIVE-INCHES: Limestone | 0 | 5 |
| | TWO FIVE-INCHES: Shale | 0 | 4 |
| | TWO FIVE-INCHES: Limestone | 0 | 5 |
| | Shale | 1 | 0 |
| | SIX-INCH. Limestone used for building; it cuts out well, but will not stand the weather | 0 | 6 |
| | Shale | 1 | 0 |
| | HOUSE PAVIOUR. Limestone; DUNCH PAVIOUR. Limestone | 1 | 1 |
| | Shale | 0 | 7 |
| | SANDSTONE. Hard limestone | 0 | 3 |
| | SECOND LIAS. Limestone | 0 | 5 |
| | Shales | 0 | 3 |
| | CLOGS. Two beds of limestone | 0 | 9 |
| | Shales with *Modiola minima* | 1 | 3 |
| | LITTLE PAVIOURS. Three bands of limestone and shales (ground up for making cement) | 0 | 9 |
| | BOTTOM LIAS. Shelly limestone with *Pleuromya crowcombeia* | 1 | 1 |
| | BURNING SCALE. Fissile limestone-shale | 1 | 6 |
| | CEMENT. Dark fissile shaly marl | 2 | 0 |
| | BLACK SCALE. Blue shaly or earthy limestone (put with CEMENT shales, for making cement, otherwise the material will not set) | 1 | 8 |
| | Grey and yellow earthy limestone, appearing to merge into the bed below. *Ostrea liassica*, &c. | 0 | 4 |
| Rhætic Beds. | DEW ROCKS. Compact limestones. (Top of White Lias.) | 1 | 7 |

A section at Puriton, showing about 30 feet of the Lower Lias with *Ammonites planorbis*, &c., was recorded by Messrs. Bristow and Etheridge.* The higher beds consist of clays with bands of limestone, so that we have evidence, confirmed by the new railway-cuttings between Bridgwater and Edington, that the zones of *Ammonites angulatus* and *A. Bucklandi* are not represented by any great mass of limestones in this neighbourhood. This was to be inferred from the clayey character of the northern slopes of the Polden Hills, and of the island of Lias that appears in the moors at Meare, where we find clay with only occasional bands of limestone.

In a quarry at Bawdrip, adjoining the new railway to Edington, the lower beds of the Lower Lias were exposed to a depth of 20 feet. They consist of thick layers of argillaceous limestone and slaty marl, on the horizon of the limestones worked at Dunball.

In the railway-cuttings near by, and onwards to Cossington, we find a considerable development of the higher blue shales and

* Vertical Sections (Geol. Survey), Sheet 46 No. 1.

clays, with bands of marly limestone, and sometimes hard and compact beds, even-bedded or nodular, that represent mainly the zone of *Ammonites Bucklandi.* Near King's Farm these beds were seen to dip in a northerly direction, and to be faulted in three places. Beyond, in the direction of Cossington, the beds are bent into an undulating synclinal fold, and thence outcrop for some distance with regularity, dipping in a southerly direction at an angle of about 15 degrees. In this great series, which may be estimated at 160 feet thick, there is a band of limestone to about every 4 feet of clay, and these beds may be traced on, until they are underlain by 20 feet of the lower limestones belonging to the zone of *Ammonites planorbis.* Very few fossils appear in the beds, but *Ostrea liassica* ranges about 50 feet above the basal limestones

I have been informed by Mr. Henry Corder, of Bridgwater, that some large Ammonites were obtained, also *Nautilus*, large specimens of *Lima gigantea*, some with *Ostrea* attached to them, *Gryphœa arcuata*, and *Rhynchonella calcicosta.* Mr. J. F. M. Clarke (the Resident Engineer), who kindly accompanied me along the railway, obtained bones of *Ichthyosaurus*, Coprolites, small specimens of *Cypricardia*, *Lima tuberculata*, and *Pecten suttonensis* (*P. Pollux*).*

In the lower limestones, Mr. Corder has noted a bed, about 6 feet above the White Lias, crowded with *Pleuromya crowcombeia*, as at Dunball. Remains of *Plesiosaurus* were found east of Cossington. Here also *Ammonites planorbis* occurs in abundance, and some remains of *Otozamites* were obtained by Mr. Clarke. The beds are faulted at many places along the railway, but the southerly dip, before mentioned, helps to bring up the Rhætic Beds near Cossington. They are well shown in cuttings by the railway-station. The junction-beds were as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Lower Lias | Clays with two or three massive beds of argillaceous limestone - - - ; Clays and thin stone-beds - - - | 9 | 0 |
| | Pale laminated calcareous shales - - | 6 | 0 |
| Rhætic Beds | White Lias, four beds of pale and compact limestone, with clay partings; yielding *Pleuromya*, *Cardium rhœticum*, *Lima prœcursor*. - - - - The lowest bed resembles Cotham marble in texture. | 4 | 9 |
| | Bluish-grey and yellow shaly clay with "race" - - - - - - | 4 | 6 |
| | Bed of hard banded limestone - - | 1 | 1 |
| | Dark blue and black paper-shales rusty at top, with thin limestone-layers and nodules of limestone, exposed to depth of - - | 16 | 0 |

The uppermost clayey division of the Lower Lias, occurs over the flat meadow-land bordering the Marlstone escarpment, at Long Load, Martock, Ilchester, Mudford, Marston Magna, and

* Identified by G. Sharman. See account of railway-cuttings, with diagram-section, by J. F. M. Clarke, Proc. Bath Nat. Hist. Club, 1891, vol. vii. p. 127.

Rimpton. North of Camel Hill, the clays occupy the surface at Sparkford, North and South Barrow, Babcary, Wheathill, and East Lydford, whence they extend around Hornblotton in the country north-east of the river Brue, to the foot of Pennard Hill. (See Figs. 43, p. 90, and 84, p. 263.)

The clays are worked here and there for brickmaking, &c., as at Butleigh, and near North Barrow, and they have been exposed in some of the railway-cuttings.

The beds contain occasional bands of limestone, as at Stone, near Hornblotton. These stone-beds sometimes furnish a limited supply of water. Thus on Southwood Common, near Evercreech, a well, sunk 10 feet in sandy shale and marl, found water; while at a short distance to the north-west by the high road, a well was sunk 60 feet deep, and yielded little or no water.

One of the most interesting fossil-beds in the Lower Lias clays in this area, is the famous Ammonite-marble of Marston Magna north-east of Yeovil. Various accounts have been published of the discovery of masses of this stone, which consists almost entirely of small Ammonites whose white pearly layer is well preserved. They comprise *A. obtusus* and *A. planicosta.* Like a bed, previously noticed, at Lyme Regis, it belongs to the zone of *Ammonites obtusus,* sometimes locally termed the zone of *A. planicosta.* According to Maton the stone was discovered in 1778 in the opening of a marl-pit;* but a specimen of it, in the British Museum, was in the original collection of Sir Hans Sloane, who died in 1753.

I am informed by Mr. Alfred Gillett, that a large and apparently nodular mass of this stone was obtained at Marston, when a well was sunk about the year 1815; and this mass, weighing a ton or more, supplied many of the specimens known from this locality. On inquiry I ascertained that a well had been sunk near the church, to a depth of about 70 feet, and that the stone had been obtained there, though at what depth was not known. Sowerby observed that it was found "in moderate masses, occasionally big enough to form tolerable sized sideboards."† Being polished in the neighbourhood of Yeovil, some confusion has arisen on the application of the term "Yeovil Marble;" a term given by some to the Forest Marble of Long Burton, and by others to the Marston Marble.‡

A specimen of *Ammonites Dudressieri* (an old form of *A. planicosta*), has been obtained by Mr. Gillett in a limestone-nodule from the Lower Lias clay of Northover, near Glastonbury.

Evidence of the zone of *Ammonites oxynotus* was to be found in the banks of the Brue above Hornblotton Mill, where beds of stiff blue and bluish-grey clay are exposed here and there beneath the valley-gravel. In 1868 I collected a number of small

* W. G. Maton, Observations on the Western Counties, vol. ii. p. 21.

† Sowerby, Mineral Conchology, vol. i. p. 167, and Tab. 73, and 406. The *A. Smithi,* Sow., is regarded by Wright as a young form of *A. obtusus.*

‡ J. Townsend, Character of Moses, pp. 105, 275.

Ammonites many of them pyritic, including *A. oxynotus*, *A. Birchii*, and *A. trivialis*.

Lower down the bed of the stream, bands of stone occur here and there in the clays, giving rise to ledges that form small cascades along the course of the stream.

The brickyard south-west of Hornblotton Mill, showed about 12 feet of blue shaly clay passing up into grey and brown clay, with a layer of septarian nodules. Here I obtained *Ammonites semicostatus*, and *Avicula*.

From the bluish-grey marly and slightly micaceous shale, thrown up during a well-sinking west of Sutton near Alhampton, I obtained a number of small pyritic fossils, including *Ammonites Birchii*, *A. Simpsoni* (not previously recorded from the south of England), *Gryphæa*, *Avicula*, and *Pecten*. It is interesting to learn that in 1729 J. Woodward noted that Ammonites occurred in vast numbers in a marl-pit at this locality.*

Blue clay weathering brown on top, with impersistent bands of earthy limestone, containing much iron-pyrites, and numerous small Ammonites, including *A. oxynotus*, *Belemnites*, *Rhynchonella*, &c., was exposed in cuttings near the Evercreech station, and near Priestleigh. But I obtained no fossils in the excavations north of Evercreech station, at the Somerset Pipe, Tile, and Brick Works, where grey slightly micaceous clays with a layer of cement stones, were exposed.

### *Shepton Mallet, Wells, and Uphill.*

Proceeding towards the Mendip Hills, there is evidence on the north of Pennard Hill of a greater development of limestone in the zone of *Ammonites Bucklandi*, than has been noticed elsewhere in Somersetshire on the south side of Mendip. There is also some attenuation in the beds below.

In the railway-cutting west of Pylle station, there may be seen about 10 feet of blue shaly clays, containing *Rhynchonella calcicosta*, *Pecten*, and *Rhyncholites*. The clay rests on a band of limestone with large specimens of *Lima gigantea*, and on alternating beds of grey earthy limestone and dark shales. At the quarry belonging to the Somerset Lime and Cement Company, lower beds are shown as follows:—

| | | |
|---|---|---|
| Lower Lias - | Marly limestones and clay - - - | 32 feet. |
| | Grey limestones and clays or shales with *Ammonites Bucklandi* - - - | |
| | Limestones, about 15 bands, with thin partings of shale - - - | |

The beds of bluish and yellowish clay and limestone present a riband-like appearance, the stone being iron-stained on the joint-faces. Pyrites occurs here and there in thin layers. Fossils are scarce, but large specimens of *Lima gigantea*, *Gryphæa arcuata*, *Ostrea irregularis*, and bones of *Ichthyosaurus* are to be found. The stone is burnt for the preparation of lime and selenitic cement.

* Nat. Hist. Foss. England, vol. i. Part 2, pp. 26, 27.

In a quarry north of Street, near Pylle, the same beds have been exposed, yielding *Pholadomya*, and other fossils. *Lima pectinoides* also occurs in this neighbourhood. These beds belong to the zone of *Ammonites Bucklandi;* and it is likely that they are faulted on the south, owing to the nearness of the Middle Lias on Pennard Hill.

Northwards, at Beard Hill and around Pilton, the beds are clearly faulted, mostly in an east and west direction, roughly parallel with the folds in the older rocks of the Mendip Hills. Fractures and disturbances have in places modified the particular relations of the Lias to the Mendip range. Near Shepton Mallet and Wells, the Lower Lias extends on to the older rocks of Mendip; and judging by the outliers of Harptree Hill and Ashwick, it evidently crossed the plateau in places, if it did not entirely envelope that region. Westwards at Wedmore the beds dip away from the Mendips.

West of Pilton a quarry showed blue limestones and clay with *Ammonites planorbis* and *A. angulatus*, capped by white rubbly and marly limestones and clay. These pale limestones were shown also in a quarry north of Westholme House, and in the Great Western railway-cutting west of Shepton Mallet (p. 87).

A section on the Somerset and Dorset (Midland) railway, east of Cannards Grave, and south of Shepton Mallet, showed the following section:—*

| | | | Ft. | In. |
|---|---|---|---|---|
| Lower Lias. | Zone of *Ammonites oxynotus*. | Dark bluish-grey mottled limestone (full of Belemnites), pale marly beds, earthy and iron-shot limestone and clay - about | 6 | 0 |
| | | Thin stone and clay. | | |
| | | Blue clay with bands of grey earthy limestone, yielding small pyritic Ammonites, *A. oxynotus, A. bifer, Belemnites, Avicula, Gryphæa arcuata, Lima, Pecten, Rhynchonella variabilis, Pentacrinus*, &c. about | 30 | 0 |
| | Zone of *Ammonites Bucklandi*. | Hard blue sandy limestone, weathering yellow: *Ammonites Conybearei* - - Massive even-bedded limestones (8 or 9 beds): *Nautilus, Gryphæa arcuata* - - | 8 | 0 |
| | | Thin irregular limestones and blue shaly clays, in riband-like beds—the stone-beds stained yellow in places. *Ammonites Bucklandi, Lima gigantea* (large) - - | 23 | 0 |
| | Zone of *Ammonites planorbis*. | Hard marly limestone - - - | 0 | 6 |
| | | Grey marly clays with indurated band: *Modiola minima* - - - - | 1 | 3 |
| Rhætic Beds. | White Lias. | Mottled somewhat earthy limestone, like Sun-bed in places - - - Hard compact limestone - - - White Lias limestones and bluish marly shales, with beds of creamy and bluish limestone: *Modiola minima, Ostrea liassica* | 6 | 0 |

* See also Geol. East Somerset, &c., p. 101.

At Shepton Mallet a fine section of Lower Lias and Rhætic Beds was exposed in the cutting west of the Great Western railway-station. This was described by Charles Moore, and the section was afterwards measured by Messrs. W. A. E. Ussher, J. H. Blake, and myself,* while a number of fossils were collected by R. Gibbs, and identified by Mr. Etheridge.

The beds shown may be summarized as follows; the species within square brackets are given on the authority of Charles Moore:—†

| | | Ft. | In. |
|---|---|---|---|
| Zone of *Ammonites Bucklandi*. | Hard blue and grey limestones mostly uneven, with alternate bands of blue and brown clay. *Ammonites Bucklandi, A. Conybearei, A. angulatus*, [*Nautilus striatus, Chemnitzia nodulosum*], *Pleurotomaria, Cardinia, Gryphæa arcuata, Lima gigantea, L. antiquata, Pecten, Pholadomya prima, Unicardium cardioides, Terebratula*, [*Spiriferina Walcotti*], *Pentacrinus* - about | 12 | 0 |
| Zone of *Am. angulatus*. | Pale rubbly limestones and clays - - | 1 | 11 |
| | Pale bluish-grey limestone. *A. angulatus* - | 0 | 4 |
| Zone of *Am. planorbis*. | Hard and soft blue and grey limestones, separated by bands of dark blue clay. *Ammonites planorbis*, [*A. Johnstoni*], *Cardinia, Lima gigantea*, [*L. tuberculata*], *Ostrea liassica*, [*O. intusstriata*], *Pecten Pollux, Rhynchonella calcicosta* - about | 5 | 0 |
| | White Lias. | | |

Among other fossils collected, were *Hemipedina, Modiola minima, Ostrea multicostata*, and *Cryptænia rotellæformis*. As Moore has pointed out, the beds yield some of the forms characteristic of the Sutton and Southerndown Beds in South Wales; but we have no indications in this section of the peculiar lithological characters seen in the Lias of Downside, Shepton Mallet, although the upper beds in this railway-cutting become rather more sandy and more closely-bedded than the lower, as do some of the upper beds of limestone in the section (previously noted) east of Cannard's Grave. It is noticeable, however, that many Gasteropoda occur, especially in the Zone of *A. Bucklandi*; among these, Moore recognized *Cerithium nodulosum*, and species of *Turritella, Littorina, Pleurotomaria*, &c. In the same beds a number of Foraminifera and Ostracoda were found.

The limestone-beds seen near Cannard's Grave, are exposed also near the Midland railway-station at Shepton Mallet, where a quarry showed about 22 feet of blue and grey limestones, separated by thin shales. The stone, which is burnt for lime, yields *Lima gigantea*, *Gryphæa arcuata*, and fine specimens of *Ammonites Bucklandi*, 2 feet in diameter. The full thickness of the Lower Lias stone-beds is upwards of 50 feet.

Still further north, we come to the area of the "Lias Conglomerate," although actual conglomerate is the exception. The beds consist of sandy, granular, and shelly limestones, some of

* Vertical Sections (Geol. Survey), Sheet 46, No. 15.

† Moore, Quart. Journ. Geol. Soc., vol. xxiii. pp. 505–510. See also Wright, Lias Ammonites (Palæontogr. Soc.), p. 12.

them identical in character with the white beds at Sutton in Glamorganshire, as pointed out by De la Beche.* In both cases, the beds rest directly on the Carboniferous Limestone (see Fig. 43, p. 90), and therefore it can hardly be questioned that their characters are due to the same causes. They are in fact, granular beds of limestone of detrital origin, derived largely from the destruction of the Carboniferous Limestone. In some cases, moreover, on the Fosse road, north of Shepton Mallet, and again in Glamorganshire, as I know from personal experience, it is very difficult on a first inspection, to distinguish the thick beds of Lower Lias where the clay-divisions are absent, from the Carboniferous Limestone—a fact pointed out by De la Beche.

These beds have been exposed to a depth of 20 feet in the road-cutting leading from Shepton Mallet Church towards Downside, and south of the Midland railway; and also in a quarry by the side of the viaduct that crosses the road. No marked divisions occur in the series, which comprises thin beds of limestone with ferruginous specks, passing down into massive beds of hard pale-grey, buff, and white sandy and granular limestone with but little clay, and with chips of chert. There is an impersistent bed of conglomerate 6 inches thick (seen in the quarry), and it is composed mostly of chert, with some pebbles of Carboniferous Limestone. A few quartz pebbles occur, and they are also occasionally to be seen in the ordinary beds of Lower Lias, exposed at Shepton Mallet: no doubt they are derived from the conglomeratic beds in the Old Red Sandstone of Mendip.

The lowest beds consist of a shelly rock with casts of *Modiola*, *Ostrea liassica*, *O. multicostata* (*arietis*), and *Lithodomus*. These soft shelly beds were exposed also at Bowlish, where *Lima* occurred abundantly.

Many other species have been recorded from these rocks. In the Museum at Jermyn Street there are specimens of *Pecten Pollux* (or *suttonensis*), *Lima tuberculata*, *L. punctata*, *L. duplicata*, *Hinnites*, and *Pecten insignis*, which were collected by Mr. Alfred Gillett. Moore has published a more considerable list,† but there has been much difference of opinion about the precise identification of some of the fossils, and the same difficulty occurs with respect to the Sutton and Southerndown species. Quite recently, the Rev. H. H. Winwood has obtained specimens of *Ammonites Johnstoni* and *Lima gigantea*: an interesting discovery, as the Ammonite has not previously been recorded from the white granular limestone of Shepton Mallet.

The evidence, as in South Wales, is in favour of the beds belonging for the most part to the zone of *Ammonites planorbis*, but including in this locality portions also of higher zones.

The road between Bowlish and Windsor Hill has been excavated where the railway crosses it, and here beds of Lias lime-

* Mem. Geol. Survey, vol. i. p. 276. Buckland and Conybeare, Trans. Geol. Soc., ser. 2, vol. i. p. 303.

† Quart. Journ. Geol. Soc., vol. xxiii. p. 509.

stone of the ordinary type have been exposed. At Windsor Hill the cutting at the entrance of the tunnel, shows the Lias faulted against the Carboniferous Limestone. From this locality Moore obtained many fossils indicating the zones of *Am. angulatus* and *A. Bucklandi*, and including many species found in the conglomeratic Lias of South Wales. To the north-west, the conglomeratic beds of Lias extend by Chilcot to East and West Horrington.

The higher division of the Lower Lias, noticed in the railway-cutting by Cannard's Grave, is worked to the east for the manufacture of red bricks, drain-pipes, and tiles. It consists of blue slightly calcareous clay, weathering brownish-yellow, and contains occasional layers of cement-stone. Northwards, clayey beds extend along the base of the Inferior Oolite series, at Doulting and Chelynch: but we have no evidence at present to say whether Middle and Upper Lias are to any extent represented at those localities. Near Bodden, it is possible that some of the higher stages of the Lower Lias may be present in the form of limestone, as we find to be the case near Radstock; but palæontological evidence is wanting.

Beds of conglomeratic Lias limestone were exposed in a swallet-hole by the Seven Acres Spring on the south side of Beacon Hill. The limestone, which is pale grey and very tough, contains tiny pebbles of quartz, scattered through the mass of the rock, and clustered together here and there abundantly. The surface-boundary of the Lias and Old Red Sandstone here corresponds roughly with the underground boundary of Lower Limestones Shales and Old Red Sandstone, the Shales being concealed locally by the Lias. Hence it is that Swallet Holes occur in this tract where the Lias is banked up against the Old Red Sandstone. Through the kindness of Sir R. H. Paget, I had the opportunity of breaking up some large blocks of this Lias limestone, but no fossils rewarded the labour. The stone was formerly quarried by Beacon Hill Farm. (See Fig. 43.)

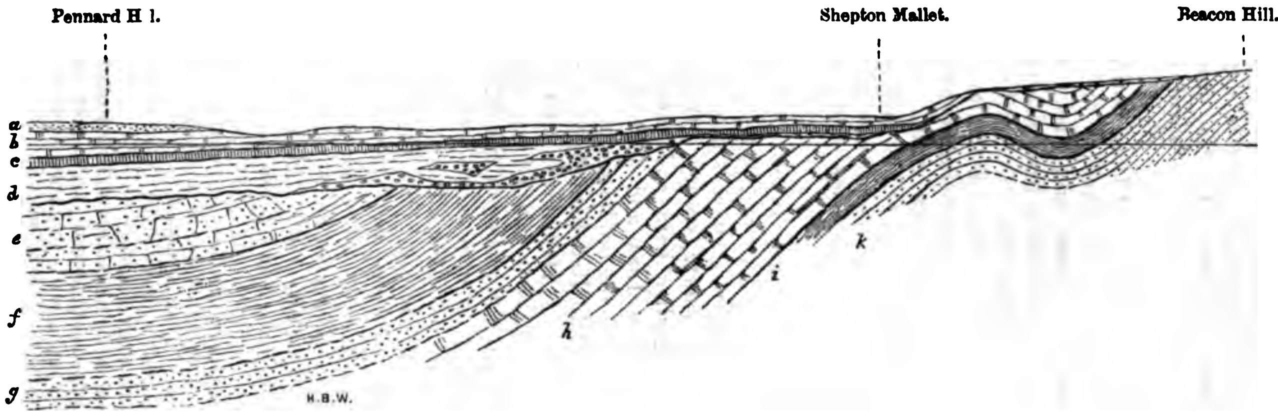
The Lower Lias limestones have been quarried north-east of Wallcombe near Wells, while in a lane-cutting near East Milton, a section showed the sequence of beds down to the White Lias, &c. Attention was first directed to this exposure by the Rev. P. B. Brodie.* The beds were as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Zones of *Ammonites Bucklandi* and *A. angulatus*. | Bluish-grey argillaceous limestones, irregular, and separated by beds of blue and brown clay. *Lima gigantea* - - - - | 26 | 0 |
| | Hard and compact light grey limestones with thin shaly partings . - - - | 7 | 0 |
| Zone of *A. planorbis*. | Hard marly limestones and slaty marls - | 2 | 7 |
| | Hard smooth-jointed bluish-grey limestones, becoming marly in places, separated by shaly bed with *Modiola minima* - - - | 1 | 10 |
| | Marly bed with *M. minima* - - - | 0 | 5 |
| Rhætic Beds. | Compact bluish-grey limestone (Jew Stone) - | 0 | 10 |
| | White Lias. | | |

* Quart. Journ. Geol. Soc., vol. xxii. p. 93; see Vertical Sections, Geol. Survey, Sheet 46, No. 14.

FIG. 43.

*Section from Pennard Hill to Beacon Hill (Mendip Hills).*




*a.* Middle Lias.
*b.* Lower Lias.
*c.* Rhætic Beds.
*d.* New Red Marl and Dolomitic Conglomerate (Keuper).
*e.* Pennant Grit (Middle Coal-measures).
*f.* Lower Coal-measures.
*g.* Millstone Grit.
*h.* Carboniferous Limestone.
*i.* Lower Limestone Shales.
*k.* Old Red Sandstone and Conglomerate.

Here the junction with the White Lias is not so clearly defined as it is in the railway-cutting west of Shepton Mallet: but it is noteworthy that the Lias limestones present their ordinary characters, in proximity to the Mendip range. The Lower Lias limestones are well shown in places south-west of Wedmore, near Heath House, where the beds resemble those near Shapwick and Ashcot on the Polden Hills, and the lower beds at East Milton: they contain *Ammonites planorbis* and *Ostrea liassica.*

The Lower Lias is exposed in the railway-cutting near Uphill, where it is faulted abruptly against the Carboniferous Limestone. The fault, which is a reversed one, was depicted in sections drawn by the Rev. D. Williams,* William Sanders, and others.† Beneath the Lias, the Rhætic Beds and Keuper Marls are exposed, faulted in several places. The Lias presents its ordinary characters, as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Zone of *Ammonites Bucklandi*, &c. | Alternate beds of light-coloured limestone and shale, with *Lima gigantea* - - | 10 | 0 |
| Zone of *A. planorbis*. | Dark grey laminated shales and thin bands of limestone, with *Ammonites planorbis* - | 14 | 0 |
| | Dark shales and bands of limestone with *Ostrea liassica* - - - - - | 7 | 4 |
| Rhætic Beds. | Alternations of limestone and marl, with *O. liassica*, and *Modiola minima* - - | 12 | 0 |

It is noticeable here, that the White Lias becomes more marly in character, so that the limestones, as at Penarth, are subordinate; moreover there is no great development of Lower Lias limestones, the beds belonging to the zone of *Am. Bucklandi* being represented, as on the Polden Hills, mainly by clay.

### *West Somerset.*

The Blue Lias series is well exposed in the cliffs of West Somerset, between Sturt Point and Blue Anchor. The eastern part of this coast-line is far from accessible, and has not attracted much notice from geologists; but all along, many instructive sections are to be seen, while the numerous faults and the effects of denudation form interesting subjects for study. (See Fig. 44.)

Probably the earliest reference to the Lias in this area was made by Leonard Horner,‡ and long subsequently it was noticed

* Trans. Geol. Soc., ser. 2, vol. vi. p. 562; Proc. Geol. Soc., vol. iv. p. 294; and Quart. Journ. Geol. Soc., vol. i. p. 48.

† Geol. East Somerset, Plate III. p. 24; and H. B. Woodward, Geol. Mag. 1870, p. 239; Geol. Eng. and Wales, Ed. 2, p. 14; H. W. Bristow and R. Etheridge, Vertical Sections (Geol. Survey), Sheet 46, No. 3; Wright. Quart. Journ. Geol. Soc. vol. xvi. p. 383, and Lias Ammonites (Palæontogr. Soc.) p. 11; Moore, Quart. Journ. Geol. Soc., vol. xvi. p. 445; and W. J. Sollas, Proc. Geol. Assoc. vol. vi. p. 385.

‡ Trans. Geol. Soc., vol. iii. p. 367.

by De la Beche, and some of the sections have been described by W. Boyd Dawkins, H. W. Bristow, and R. Etheridge.*

During the years 1871–3, Mr. J. H. Blake was engaged in a re-survey of the Secondary tracts in West Somerset, and he then revised the boundaries of the Lower Lias, and marked with great care the exposures of beds on the foreshore and the numerous faults that affect them.

The strata that are shown, include the zones of *Ammonites planorbis*, *A. angulatus*, *A. Bucklandi*, and *A. semicostatus* (or *A. Turneri*). No representatives of any beds as high as the zone of *A. oxynotus*, are known to occur in the area.

As on the opposite coast of Glamorganshire, the beds, which consist of a series of limestones and shales or clays, are by no means rich in fossils, though here and there layers occur that abound in organic remains, or these may be met with in patches or shoals in otherwise unfossiliferous rock.

Owing to the extent of coast-line, the inaccessibility of certain portions, and the numerous faults and undulations, it is difficult to determine the limits of the several divisions, and to measure with accuracy the thickness of the beds. Here and there the Rhætic Beds or New Red Marls form the mass of the cliffs.

We find in the lowest division (zone of *A. planorbis*) that limestones are not so prominently developed as at Street and at Lavernock, but these beds are surmounted, as at Lavernock, by a grey marl division that may be grouped with the zone of *Ammonites angulatus*. Still higher we come to the main mass of blue limestones, which here, as at Dunraven and eastwards on the Glamorganshire coast, belongs to the zone of *Ammonites Bucklandi*. Above these beds there is again a considerable thickness of grey marls with subordinate bands of argillaceous limestone. These represent the zone of *Ammonites semicostatus*, and may perhaps include portions of still higher beds, for west of Kilve I obtained a specimen, doubtfully referred by Messrs. Sharman and Newton to *A. densinodus*.

The following is the general succession of the strata seen along the coast of West Somerset:—

| | | Ft. In. | Ft. In. |
|---|---|---|---|
| Zone of *Ammonites semicostatus.* | 5. Dark grey shaly marls with thick bands of argillaceous limestone, and, near the base, a conspicuous band of paper-shales. Seen in cliffs above the cave east of Kilve Pill, by Kilve Farm and westwards to Quantockshead; also near Donniford Kiln, by the Bathing Cove at Watchet, and to the east of Blue Anchor. Large Ammonites, *A. semicostatus*, *A. Turneri*, *Cardinia*, *Pentacrinus*. | 40 0 | to about 45 0 |

* Vertical Sections (Geol. Survey), Sheet 47, No. 6; Etheridge, Proc. Cotteswold Club, vol. vi. p. 35; Dawkins, Quart. Journ. Geol. Soc., vol xx. p. 397.

| Zone | Beds | Ft. In. | Ft. In. |
|---|---|---|---|
| Zone of *A. Bucklandi.* | 4. Alternations of grey limestones, sometimes in thin bands, with shales and shaly marls, but merging into a more prominent mass of blue limestones with thin shaly marls. Seen in the cliffs at Sturt? ; also west of Little Stoke, by cave east of Kilve Pill; at base of cliffs, by gangway near Kilve Farm, and thence to Quantockshead. | 20 0 to | 25 0 |
| | 3. Alternate bands of thin blue and yellow (iron-stained) limestones, 25 or more in number, with blue and sometimes brown marly shales. The limestones being jointed and standing out irregularly, present a zig-zag appearance amongst the clays. On the whole there is a larger proportion of clay or shale, especially towards the lower part. Seen in cliffs to the west of Little Stoke; at the base of Quantockshead; upper part of St. Audries. Portions of this division are faulted against the Keuper Marls at the Bathing Cove, Watchet. These stone-beds yield *Ammonites Bucklandi, Nautilus, Pleurotomaria, Gryphæa arcuata, Lima gigantea, Rhynchonella calcicosta, Pentacrinus.* | About 40 0 | |
| Zone of *A. angulatus.* | 2. Dark grey shale and grey marl with only occasional bands of limestone. Seen at several points at base of cliffs between Little Stoke and Kilve Pill; St. Audries. *Ammonites angulatus.* | 30 0 to | 35 0 |
| Zone of *A. planorbis.* | 1. Slaty marls, dark shales, and bands of limestone. *Ammonites planorbis, A. Johnstoni, Ostrea liassica, Pullastra arenicola* ? (with shell), *Modiola minima*. These beds rest on the White Lias Series, and may be seen at the top of the Cliff, east of Little Stoke, at St. Audries, to the west of Watchet, and near Blue Anchor. | | 20 0 |
| Rhætic Beds. | White Lias, consisting of grey shaly marls, limestone-shales, and beds of compact limestone . about | | 8 0 |

Along this coast the Lower Lias is first exposed in a low cliff, that rises to a height of 20 or 30 feet, at Sturt Point east of Benhole Farm, and to the west of Stolford. Here we find blue shaly marls and hard jointed limestones, which probably belong to divisions 4 and 5; but the only fossil I obtained was a doubtful specimen of *Ammonites semicostatus*. The limestone-bands form ledges along the foreshore, stretching in various directions according to the lie of the strata, which are repeatedly faulted. Some of these bands are much veined with calc-spar, owing no doubt to the effects of disturbance and fracture.

Old lime-kilns (mostly deserted) are to be seen here and there near the margin of the cliffs, the stone being occasionally burnt for building-lime.

To the east of Little Stoke, the New Red Marl appears at the surface not far inland, owing to faults. Hence along the coast westwards to Blue Anchor we find the cliffs changing abruptly from Lias or Rhætic Beds to Red Marls. Here and there we find large stacks of Lower Lias limestones and shales, which in some instances have broken away and slipped from faulted masses in the cliffs.

A fine section of Lower Lias and Rhætic Beds is exposed immediately east of Little Stoke gap, and these beds are faulted further east against the Lower Lias, traces of the black Rhætic shales being squeezed in along the fault-plane. The lowest beds of the Lias here consist of limestones, thin limestone-shales, and dark shales.

From Little Stoke to Kilve the beds exhibit many undulations and faults, with downthrows on the east, so that lower and lower beds are presented to view as we pass westwards, and we come to grey shales with flattened specimens of *Ammonites angulatus*, belonging to division No. 2.

A cave has been excavated in the beds at one point, and to the east of this, there is a fault with apparently a considerable downthrow on the west. Ammonites and other fossils are occasionally to be seen on the platforms of rock on the foreshore west of the cavern, but the specimens are too firmly imbedded to be hammered out.

West of Kilve and below East Quantockshead, there occur the finest of the Lias cliffs on this coast, the limestones are well-shown but they are not very accessible, for an occasional bluff or headland impedes the progress of the pedestrian. Still further westward a fault brings these Lias limestones and dark shales abruptly against the Red Marls. Thence towards St. Audries we can trace the upward succession, in highly inclined strata, from the Red Marls with bands of hard limestone, through the Rhætic Beds to the Lower Lias. (See Fig. 44.)

The Lower Lias Limestones at St. Audries consist of jointed yellow limestones and shales, resting on a thick series of grey shaly marls with occasional bands of limestone (30 or 35 feet thick), and these again repose on beds of limestone and laminated limestone-shales with *Ammonites planorbis, Ostrea liassica, Modiola minima*, &c.

Slabs covered with specimens of *Pullastra*, having the shell preserved, have been obtained from shales near the base of the Lias at St. Audries, and again by the gangway west of Watchet and near Blue Anchor.

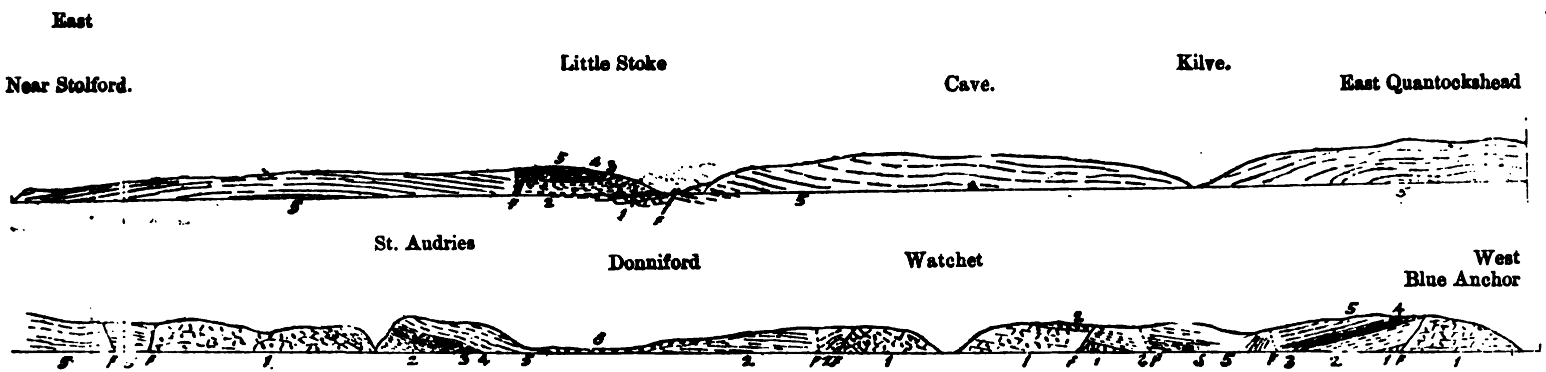
A detailed section of the Lower Lias at St. Audries, showing about 40 feet of these strata, has been recorded by Messrs. Bristow and Etheridge.* The western portion of the cliffs is not clearly

* Vertical Sections, Geol. Surv., Sheet 47, No. 6. See also Wright, Lias Ammonites (Palæontograph. Soc.), p. 12.

FIG. 44.

*Generalized Section of the Cliffs from near Stolford to Blue Anchor, near Watchet, Somersetshire.*

Horizontal Scale about 1½ inches to a mile. Vertical Scale exaggerated.




6. Gravel, &c.
5. Lower Lias.

4. White Lias.
3. Black Shales.
2. Grey Marls.
} Rhætic Beds.

1. New Red Marl (Keuper).

F. Principal Faults.

shown. The beds may possibly be faulted with a downthrow on the west.

Proceeding towards Watchet, we lose the cliffs for a short space, and pass along a beach formed largely of Lias stones, which are collected here and at St. Audries, and conveyed by donkeys to Donniford kiln. On the foreshore *Ammonites Turneri* occurs in shaly limestone, and in the low cliffs succeeding, we find shaly marls with thick beds of argillaceous limestone (belonging to Division 5). These beds are capped by gravel, which towards the east forms the whole of the low cliff, giving it a reddish-brown appearance. The stones are chiefly Devonian, Lias being rare if not absent.

Continuing towards the Bathing Cove, we find shaly marls and paper-shales much jointed, with occasional thick bands of limestone, exposed in the cliffs and on the foreshore, but faulted in places. Large Ammonites suggestive of *A. stellaris* occur, but in the cliffs at the Bathing Cove, apparently on a higher horizon, we find *A. Turneri* in beds of grey marl and shale with occasional limestone, shown to a thickness of 25 feet. These beds are faulted to the north against grey limestones and shaly marls with *Gryphæa arcuata*, strata which are themselves faulted again further north against the Keuper Marls. Whether in this district there are any marly and clayey beds above the zone of *Ammonites semicostatus* is not clear, for the beds are so repeatedly faulted; further palæontological evidence is much to be desired.

West of Watchet the Lower Lias limestones with *Ammonites Bucklandi*, have been quarried near Saxon House, and here the beds incline seawards, being however faulted against the Red Marls, &c. which form, for the time being, a protecting face of cliff. As soon as the Red Marls are denuded the Lias will rapidly break away. Between Watchet and Blue Anchor the beds are again much faulted and disturbed.

About midway there is a gap in the cliffs, on either side of which the Lower Lias is exposed. On the eastern side we find division 1: thin fissile shaly limestones breaking up into rhomboidal masses by jointing. Here the stone from the beach is hauled up an inclined plane to a lime-kiln. Iridescent Ammonites occur here, including *A. planorbis* and *A. Johnstoni*. Dr. Wright has observed that these shales yielded the original specimens of *Ammonites planorbis* and *A. Johnstoni*, figured by Sowerby in his "Mineral Conchology." The nacreous layer of the shells is beautifully preserved.*

On the west side of this gap we pass a small mass of the lower Rhætic beds and Keuper Marls, faulted against Lower Lias. These beds consist of alternations of grey earthy limestone and shale, and here some plant-remains were obtained from the Lias by Mr. S. G. Perceval. The beds are much slipped and probably

* Quart. Journ. Geol. Soc., vol. xvi. p. 384; and Lias Ammonites (Palæontogr. Soc.), p. 12.

also faulted: for they include portions of division 5, because among the wreck of marly beds we find *A. Turneri* and *A. stellaris*? Still further to the west we find the famous Rhætic section of Blue Anchor, with the basement-beds (1) of the Lower Lias on top.

It is noteworthy that in this district, where the Rhætic Beds and Lower Lias border the older (Devonian) rocks, they do not exhibit the conglomeratic conditions shown in some other places. It seems probable that the beds are faulted against the Devonian Rocks, near Selworthy, where the dip of the Lower Lias, &c. has been noted as from 15° to 23°, by Mr. J. H. Blake; at any rate we have no evidence pointing to a Liassic sea-margin anywhere in West Somerset.

### *Mendip Hills.*

It has been shown that in some places, the lower beds of the Lower Lias border the Mendip Hills and fringe its slopes, and that on its summit there are patches of Lower Lias in places. There can be no doubt, therefore, that some portions of the Mendip area were above water, either as a promontory connected with the Glamorganshire area, or as islets in the Liassic seas. It is difficult to estimate the amount of sediment accumulated on its surface, for the Liassic beds, where preserved, are not of great thickness, and show as a rule only the lower zone of *Ammonites planorbis*.

Near Frome, however, in Vallis, Nunney, and other ravines, we find an exceeding variable series of deposits resting on the Carboniferous Limestone and older rocks. In some places the Inferior Oolite rests directly on the Carboniferous Limestone; in others we find intervening beds of Rhætic age, Lower Lias and Middle Lias.

The surface of the Carboniferous Limestone as pointed out by De la Beche,* and others, is in many places planed off in a remarkably even manner, so that horizontal beds of Dolomitic Conglomerate (Trias), Lias, and newer deposits, rest on an even surface of the highly inclined Carboniferous Limestone. The surface of these older strata is not uniformly level over extensive areas; it would appear rather that, in addition to occasional islets, or other inequalities, there were various platforms upon which divisions of Lias and newer strata were accumulated in a more or less attenuated form. In some cases these deposits were removed before succeeding accumulations were laid down: so that the platform or terrace may have been formed at an earlier stage than that of the deposits now resting on it. The varying positions occupied by these Secondary strata on the flanks and higher grounds of the Mendips, are likewise in part due to marginal deposits being laid down at different relative levels, and in part to subsequent faulting or irregular elevation.

* Mem. Geol. Survey, vol. i. pp. 269, 287, &c.

Joints in the Carboniferous Limestone are infilled with various materials, for the superincumbent strata have tumbled or been washed into fissures, and we see the "broken beds" above, as in the case of Purbeck Beds where they overlie fissures in the Portland rocks.

Veins of Liassic material in the Carboniferous Limestone, have been noticed by Moore in several localities on the Mendip Hills, in the Bristol area, and in South Wales. Some of the veins traverse the rock in a direction east and west, and they are intersected by others from north to south. The veins are from a few inches to 6 feet wide, and they are accompanied by Heavy Spar, Galena, and Blende. The most remarkable discovery was made at the Charter House Lead Mine, south of Blagdon, where at a depth of 270 feet from the surface, a number of fossils were obtained, including Land-shells of the genera *Valvata*, *Vertigo*, *Proserpina*, and *Helix*, and over 50 species of Brachiopoda and Mollusca; as well as Foraminifera, Fish-remains, &c.*

The age of many species is doubtful, for Moore subsequently obtained *Planorbis mendipensis*, *Involutina liassica*, and other forms in the lead-mining districts of the North of England; † while the abundant remains of *Acrodus* and *Hybodus* are suggestive of Rhætic accumulations. It must be remembered that the remains of *Microlestes*, found in a fissure near Frome, occurred in association with in-fillings of Oolitic as well as Carboniferous age.‡

With regard to these veins, Moore was of opinion that "In general they are of Liassic age; but the mineralogical and palæontological variety they present, show that they were not formed contemporaneously. Probably they were for a long time open to the Liassic seas, and must in many instances have received their contents very gradually; a Liassic fauna not only inhabited the ocean above, but lived within the Carboniferous Limestone walls of the open fissures, and the remains of Gasteropoda and other organisms may still be seen attached thereto."|| It is possible, that there were open fissures on the sea-coast in Liassic times, as we see at the present day in the Carboniferous Limestone near Sutton in South Wales, but the admixture of fossils suggests that in-fillings may have taken place at various periods, in some cases perhaps subsequent to the Jurassic epoch. In some of their features, these Liassic veins resemble the chasms and 'pipes' in the Kentish Rag of Maidstone, where in-fillings of fossiliferous brickearth occur.§

* Quart. Journ. Geol. Soc., vol. xxiii. pp. 454, 481–495; vol. xxxvii. pp. 67, &c.; Rep. Brit. Assoc. for 1864, Sections, p. 59; Geol. Mag., 1864, p. 235.

† Rep. Brit. Assoc. for 1869. p. 369.

‡ Owen, Quart. Journ. Geol. Soc., vol. xvi. p. 492.

|| Quart. Journ. Geol. Soc., vol. xxiii. pp. 455, 488.

§ See Foster and Topley, *Ibid.*, vol. xxi. p. 454; and Topley, Geol. Weald (Geol. Survey), p. 179.

# CHAPTER IV.

## LOWER LIAS—(*continued*)

### Local Details.

### *Glamorganshire and Monmouthshire.*

In Glamorganshire the Lower Lias borders the southern side of the great coal-field of South Wales; and to the west of Cardiff, the Old Red Sandstone, Lower Limestone Shales, and Carboniferous Limestone, have been denuded so as to form a plain that is comparatively level when compared with the bold hills of the Coal-region on the north.

The Lias rests in places directly on these older rocks, and chiefly on the Carboniferous Limestone. In this district, as on the Mendip Hills, the Dolomitic Conglomerate had previously stretched in irregular masses over the Carboniferous Limestone, &c., so that the overlapping presents irregular modifications, the Lias resting here and there directly on the Dolomitic Conglomerate without the intervention of the Rhætic Beds.*

The peculiar characters of the basement-beds of the Lower Lias, where they rest on the Carboniferous Limestone, at Southerndown and Dunraven near Bridgend, and at other localities in Glamorganshire, were pointed out many years ago by De la Beche; he noticed that the limestones became more or less conglomeratic, and were associated with a whitish limestone known as Sutton Stone.†

Since the recognition of the Rhætic Beds in this country (1860–61), there has, however, been much discussion on the age of the "Lias conglomerate" of South Wales, and on the question whether the Rhætic Beds are or are not represented in it.

In 1863 Mr. R. F. Tomes "claimed for the basement-beds a date corresponding to the Rhætic age," on account of the presence of *Plicatula intusstriata*;‡ but this view proved to be based on an insecure foundation, for the species occurs sometimes abundantly in the Lower Lias. In 1866 E. B. Tawney expressed his opinion that the whole of the Conglomerate series was Rhætic in age;§ he divided the beds as follows:—

2. Southerndown Series (about 50 feet thick at Southerndown and about 12 feet at Dunraven).
1. Sutton Series (about 40 feet thick).

The ordinary beds of Lower Lias, overlying the Southerndown Series, were grouped by him in the zone of *Ammonites Bucklandi.*

Tawney's conclusions were shortly afterwards contested by Charles Moore,‖ H. W. Bristow,¶ and Prof. Ralph Tate,** who maintained that the beds were

* See also De la Beche, Mem. Geol. Survey, vol. i. pp. 240, 252, 274.
† Mem. Geol. Survey, vol. i. pp. 269, &c.; Geol. Observer, Ed. 2, pp. 482, &c.
‡ Proc. Cottesw. Club, vol. iii. pp. 191, 202.
§ Quart. Journ. Geol. Soc. vol. xxii. p. 69.
‖ *Ibid.*, vol. xxiii. p. 511; and Proc. Bath Nat. Hist. Club, 1865.
¶ *Ibid.*, vol. xxiii. p. 199; see also pp. 202, 203.
** *Ibid.*, p. 307.

Lower Lias; while Prof. P. M. Duncan* adopted a sort of compromise by employing the term Infra-Lias, which includes both White Lias (Rhætic Beds) and the zones of *A. planorbis* and *A. angulatus*.

Bristow, who maintained that the beds belonged to the Lower Lias, disputed the sequence pointed out by Tawney, urging that there was but one series, by whatever name it may be called; the Southerndown Series being merely the easterly prolongation and the representative of the Sutton Stone, and the total thickness being from 35 to 37 feet. He admitted, however, that as the Sutton Stone reposes on the upturned edges of the Carboniferous Limestone, and fills up irregularities and undulations in that rock, the thickness is somewhat variable in different places.

Subsequently Tawney abandoned his view on the Rhætic age of the deposits, and for a time the question appeared to be settled. In 1884, however, Mr. Tomes expressed his conviction that the conglomerate-bed at Stormy Down near Bridgend "is the true representative of the Sutton Stone of Sutton, and West of the 'Guinea' bed of Binton and Grafton in Warwickshire, and of the White Lias of that county and the West of England";† a view taken also by Mr. W. C. Lucy,‡ who had accompanied Mr. Tomes on a visit to the South Wales district. At the same time Mr. Etheridge, who had previously considered that the Sutton Stone and white conglomerate might be of Rhætic age, observed that their precise position was still an open question.§

No doubt some difficulty is experienced, in making out the precise relations of the white Sutton Stone and conglomerate, to the ordinary Lower Lias of this area. This arises in part from the cliffs being to a great extent inaccessible, while portions of the coast can only be visited for a short time when the tides are at their lowest; and we have to scramble over ragged rocks. Moreover the strata themselves are subject to variations, and are shifted in three or four places by faults, in situations where it is difficult to estimate the precise amount of the displacement. By measuring the strata in detail at several points, I was enabled in time to make out the sequence, and to satisfy myself that while the white Sutton stone and conglomerate (with occasional bluish modifications) form the base of the series, both at Sutton and Dunraven, these beds pass up insensibly into the blue and grey conglomeratic (Southerndown) beds, which are overlaid by the ordinary beds of the Lower Lias. The sequence, therefore, that was pointed out by Tawney is correct, although the Sutton Beds merge upwards into the Southerndown Series without any definite plane of demarcation. (See Fig. 45.) The total thickness of the conglomeratic series, where it could be definitely measured, varies from 50 to 80 feet, but it increases still more in its western development between Sutton and Southerndown.

The whole of these beds may be regarded as the basement-beds of the Lower Lias, representing the Ostrea-beds and other portions of the zone of *Ammonites planorbis*, and including perhaps portions of the zone of *A. angulatus*. They are overlaid conformably by limestones and shales exhibiting the ordinary characters of Lower Lias, and belonging partly to the zone of *A. angulatus*, but mainly to that of *A. Bucklandi*.

* Quart. Journ. Geol. Soc., vol. xxii. p. 89; vol. xxiii. p. 15; vol. xlii. pp. 101, 113, 189; and Supp. to Fossil Corals, Palæontogr. Soc.

† Quart. Journ. Geol. Soc., vol. xl. pp. 353, 359; see also vol. xxxviii. p. 411.

‡ Proc. Cottesw. Club, vol. viii. p. 254.

§ Quart. Journ. Geol. Soc., vol. xl. p. 375; see also Proc. Cardiff Nat. Soc., vol. iii. pp. 39–62.

Fig. 45.

*Section of the Cliffs at Sutton, Southerndown, and Dunraven, Glamorganshire.*

Horizontal Scale about four inches to a mile. Vertical Scale an inch to 400 feet.


4. Limestones and Shales (of ordinary character) }
3. Southerndown Beds - - - - } Lower Lias.
2. Sutton Beds (with caverns) - - - }

1. Carboniferous Limestone.
F. Faults (the oblique appearance of the faults on the east side, is due to the way in which they intersect the cliffs.)

The Sutton Stone has been extensively quarried near Sutton, more especially between Sutton and Sealawn, on both sides of the road, and again on the slopes facing the Black Rocks near Pant-y-Slade. The principal working in 1887, was immediately south of Tusker Cottage, and the section was as follows:—

| | | Ft. In. |
|---|---|---|
| Sutton Series. | Hard grey and white shelly limestones, with occasional pebbles of Carboniferous Limestone, and near the base a band of tolerably compact blue limestone - - - | 6 6 |
| | Massive bed of white more or less tufaceous stone of variable character, with fibrous structure here and there, and much jointed and broken up in places. (Sutton Stone proper) - - - - | 7 0 or 8 0 |

The more abundant fossils are *Ostrea multicostata*, *Plicatula intusstriata*, *Pecten suttonensis* (or *Pollux*), and *Cardinia suttonensis*; but these are not very common, and the shells are frequently dissolved away leaving the rock in a cavernous condition. I also obtained *Gryphæa*, *Hinnites*, *Lima hettangiensis*, *Ostrea arietis*, *Astrocœnia gibbosa*, and lignite.

Galena has been observed in several places in the Sutton Stone and overlying conglomeratic Beds. De la Beche observes that it occurs not only in the mass of the stone, but in joints of jet-like plants, and in cavities left by the dissolution of shells. He remarks also, that in some localities the stone is dolomitic: a specimen having been obtained at "Parc, two miles north-west of Bridgend."*

Passing along the coast west of the Black Rocks near Sutton, we come upon the Sutton Beds, resting directly on the Carboniferous Limestone; and the general dip of the newer beds being in a south-easterly direction, the stone, which at Sutton rises to an elevation of 200 feet, gradually descends to 50 feet and less above sea-level.

On the coast here (west of Pant-y-Slade), the beds consist of white shelly conglomeratic and tufaceous stone, containing *Ostrea*, Corals, &c.; they are variable in character, being in places coarsely conglomeratic; they show honey-combed weathering, and they rest irregularly on the Carboniferous Limestone. The basement-bed is generally the more conglomeratic, containing often large boulders of Carboniferous Limestone in a creamy limestone-matrix; but beds with no pebbles often lie in places directly on the older rock. The conglomeratic series contains curious sparry veins, sometimes tinged with a greenish colour. Corals derived from the Carboniferous Limestone, as well as fragments of chert and limestone also occur.

The connection between the white Sutton Beds and overlying bluish-grey conglomeratic limestones of the Southerndown Series, may be traced in the ravine known as Pant-y-Slade, that descends

* Mem. Geol. Survey, vol. i. pp. 272, 273; see also Bristow, Quart. Journ. Geol. Soc., vol. xxiii. p. 199; and Catalogue of Rock Specimens in the Museum of Practical Geology, Ed. 3, p. 123.

to the coast from a point north-west of the farm-buildings of West. (See Fig. 45.) Forming the higher ground here, and exposed in three scarps at successively lower levels along the borders of the ravine, there may be seen a series of blue flaggy compact and crystalline limestones, more or less conglomeratic or brecciated, and containing angular fragments of Carboniferous Limestone and chert. Some of the beds indeed are not unlike Carboniferous Limestone in texture,* and intercalated with them are thin shaly beds. The sequence in these upper beds is not sufficiently clear for detailed measurements, and it is quite possible there may be some repetition by faults. It is, however, probable that we have here a thickness of 70 or 80 feet (if not more) of conglomeratic Lias above the Sutton Beds; a view that coincides with the evidence obtained elsewhere along the coast, that the conglomeratic series thickens towards the west, and this agrees with the observations of Charles Moore.†

The lowest beds seen here in the coast-section, merge downwards into the white Sutton-stone Series, as seen in the following section of the cliff east of the Pant-y-Slade ravine :—

| | | Ft. | In. |
|---|---|---|---|
| Southerndown Series (base). | Bluish brecciated cherty limestones with veins of calc-spar - - - | 6 | 6 |
| Sutton Series. | Pale brecciated limestone with fibrous structure - - - - - | 3 | 0 |
| | Bluish-grey and pale brecciated limestones - | 3 | 0 |
| | Compact bluish limestone more or less conglomeratic, passing into white tufaceous and shelly limestone, with fibrous structure: *Pecten suttonensis* - - - | 9 | 0 |
| | Thick beds of pale tufaceous limestone with fibrous structure, and with conglomeratic bands here and there - | 10 0 to 12 | 0 |
| | Massive beds of pale brecciated limestone, passing down into conglomerate of irregular thickness : *Pecten suttonensis, Ostrea multicostata*, Corals - - | 5 to 16 | 0 |
| Carboniferous Limestone. | | | |

It may be questioned whether the top 6 feet of strata, here included with the Sutton Series, should be so grouped; the evidence obtained at Witches Point favours the view adopted, but the question is of no importance. We have, however, near Sutton, a thickness of from 25 to 40 feet of strata that may be assigned to the Sutton Series, for their thickness increases eastwards in places according to the irregularities on the surface of the Carboniferous Limestone. There can be no question of the intimate connection between the Sutton and Southerndown Series; and the higher beds of blue conglomeratic limestone seen here, are similar to those seen above the white Sutton Beds on the southern side of Witches Point, where the thickness of the Southerndown Series is much reduced.

The higher beds in the Pant-y-Slade ravine have not proved to be fossiliferous, so that we are not in a position to state whether the greater thickness of the conglomeratic beds is due solely to an

* See also De la Beche, Mem. Geol. Surv., vol. i. p. 272.

† Quart. Journ. Geol. Soc., vol. xxiii. pp. 526, 531; Tomes, *Ibid.*, vol. xl. p. 357.

expansion of the Southerdown Series, or (as seems probable) to the formation as we proceed westwards, of conglomeratic beds at higher stages in the Lower Lias.

Passing eastwards along the coast, over the irregular surface of the Carboniferous Limestone, we find the pale Sutton Beds banked up against the older rock (see Fig. 45), and at the base of the first cave they occupy a large hollow eroded in that rock, and descend to the beach-level. Here the Sutton Beds are 40 feet or more in thickness, and it may be noted that the lowest bed of conglomerate is very coarse, and of a bluish colour, similar to the basement-bed on the further side of Witches Point.

Beyond this first cave, the Carboniferous Limestone again rises, and we may readily follow the pale Sutton Beds, which appear in marked contrast with the dark bluish-grey Carboniferous rock beneath. Both groups have an easterly dip, and the stratification in places is fairly conformable, but further east the Carboniferous Limestone rolls over abruptly in the same direction, and the discordance between it and the overlying strata is great.

The Sutton Beds appear now as massive strata assuming a brown aspect where weathered, and the lower layers are very irregular in thickness. We can fix no divisional line between them and the overlying Southerndown Beds, for the cliffs, which rise to a height of nearly 150 feet, are for the most part perpendicular. The Sutton Beds however gradually descend to the sea-level by the large "Fairy Cave."* To the east of this, their prolongation on the foreshore is terminated by a fault; but they are again upraised, for a space, a little further on by another fault, being seen only in ledges on the foreshore. Thence they do not reappear until we come to the cliffs on either side of the Witches Point at Dunraven, as observed by Tawney and others.

From the Fairy Cavern eastwards, we can again note the upward succession of the beds from the base of the Sutton Series into the lower portion of the Southerndown Beds, but the cliffs above are inaccessible. Here we find on top of the Carboniferous Limestone, a thickness of 25 feet of pale conglomeratic limestones, alternating with pale limestones like the Sutton Stone. These, as at Sutton, are surmounted by grey and bluish-grey limestones (4 feet 6 inches thick), which form a connecting link with the conglomeratic limestones of the Southerndown Series above. In these the limestones become streaked with indurated shaly bands, which present a wavy appearance. Here the highest bed we can reach is about 50 feet above the Carboniferous Limestone; it is a limestone with prominent fucoidal markings, but bands of this nature occur at various horizons in the Southerndown Series, and also in the ordinary beds of Lias above.

Passing by the faulted tract to the east, where three great buttresses of rock with perpendicular faces are presented to view, we come to what may be termed the main section of Southern-

* See Sections by Tomes, Quart. Journ. Geol. Soc., vol. xl. p. 357; and Lucy, Proc. Cotteswold Club., vol. viii. Section D., p. 254.

down, for the beds may be traced eastwards continuously, past Southerndown beach to the cliff by the fault west of Dunraven Castle. That in this division of the cliffs the sequence is clear, may be proved by detailed measurements of the beds at either end of the beach; and by observing the continuity of a thick and prominent band of limestones (with little shale), that occurs near the upper part of the Southerndown cliff and appears again on the Dunraven side of the little bay. (See Fig. 45.)

In the entire section, about 180 feet of ordinary Lower Lias limestones and shales have been exposed, and of these beds about 100 feet are shown in the Southerndown cliff. These beds rest on a series of hard and more massive beds of bluish conglomeratic limestone and shale (Southerndown Series) that form the base of the cliffs; and, as the strata undulate, the sequence can be traced upwards from the lowest bed exposed on the foreshore at the western end of the bluff, and again further eastwards, where the ledges and platforms of rock stretch out seawards for some distance. Unfortunately in these exposures we do not find evidence of the white Sutton Stone and conglomerate anywhere along the base of the cliffs or foreshore. Bristow's section was evidently taken from this portion of the cliffs, and consequently it did not show the Sutton Stone that underlies the Southerndown Beds. He notes the occurrence of an irregular layer of black chert, in addition to the derived fragments of this rock; and Conybeare noted that specimens of *Gryphæa*, coated with chalcedony, were to be found in the Lias of this area.* In order to make clear the sequence we must carry our investigations further eastwards beyond the Witches Point.

The section of the beds at Southerndown, traced westwards from the fault seen in the cliffs east of Southerndown beach, and near Dunraven Castle, is as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Zone of *Ammonites Bucklandi*, &c. | Limestones and shales (mostly inaccessible). *Unicardium cardioides* and *Gryphæa arcuata* in lower beds - - About | 100 | 0 |
| | Thick and prominent mass of irregular limestones and marly clays - - - | 10 | 0 |
| | Alternate bands of earthy, compact, and shelly limestone, and dark shale: yielding *Ammonites Bucklandi*, *Gryphæa arcuata*, *Ostrea*, *Unicardium*, lignite - - | 65 | 0 |
| Southerndown Beds. | Hard grey and conglomeratic limestones with thin shaly beds. Gasteropods abundant in different layers of limestone. *Cerithium*, *Littorina*, *G. arcuata* - - - | 5 | 6 |
| | Hard grey limestones, conglomeratic, and with obscure shaly layers. *Ammonites*, lignite - - - - - - | 4 | 3 |
| | Hard blue and grey limestones, with occasional conglomeratic beds, cherty limestone, and indurated shale - - | 24 | 3 |
| | Hard blue limestone, with chert fragments; Gasteropods - - - - - | 1 | 0 |
| | Hard blue conglomeratic limestones, with indurated shaly bands. Seen to depth of | 13 | 0 |

* Conybeare and Phillips, Geol. Eng. and Wales, p. 265; see also J. J. Conybeare, Ann. Phil., 1822, p. 336.

Tawney estimated the thickness of the Southerndown Series in this section at 50 feet; so that our measurements well agree.

In the south-eastern angle of the bay, on the western side of Witches Point, there is a fault and much disturbance of the strata. The Lower Lias limestones and clays on the north, are brought abruptly against the conglomeratic beds of Lias, the Sutton Stone and conglomerate, and the Carboniferous Limestone on the south: and the downthrow on the north must amount to about 100 feet. The beds on the northern side of Witches Point are for the most part inaccessible, but their general arrangement may be studied from the shore. The White conglomerate is seen to rest irregularly, and with varying thickness, on the Carboniferous Limestone, which here contains many nodules and lenticular bands of chert, and exhibits an undulating anticlinal structure. (See Figs. 45 and 46.) Beyond the Witches Point the

FIG. 46.

*Section near the Witches Point, Dunraven, Glamorganshire.* (De la Beche.)


*c.* Southerndown Beds. } Lower Lias.
*b.* Sutton Beds. }
*a.* Carboniferous Limestone.

beds are more accessible at low-tide, and here the Sutton Stone inosculates with the older rocks, having undercut it in places; a feature also observable near Sutton.

The main mass of white stone and conglomerate forming massive beds, here occurs at the base, as in the cliff at Pant-y-Slade; it is from 20 to 25 feet thick, but above are nearly 20 feet of blue, bluish-grey, and pale-grey limestones that contain the same fossils and cannot be separated from the Sutton Series. Higher still, we can just trace the more decidedly bluish-limestones, more or less conglomeratic (Southerndown Series), that underlie the ordinary beds of Lower Lias.

Along this part of the coast the sequence is interfered with by an occasional dislocation of the beds. On the eastern side of Witches Point there is a cavern, excavated in the white Sutton Beds which rest on the Carboniferous Limestone. The basement Sutton conglomerate contains fragments of chert, and pebbles or boulders of Carboniferous Limestone. It is here 9 feet thick, and is overlaid by about 18 feet of pale limestones more or less brecciated. We are unable to trace the sequence

continuously from this point, as a little further north there is a small fault or joggle, the precise throw of which it is difficult to determine, but it appears not to exceed about 4 feet on the further side towards Dunraven. It suffices however to carry the Carboniferous Limestone out of sight.

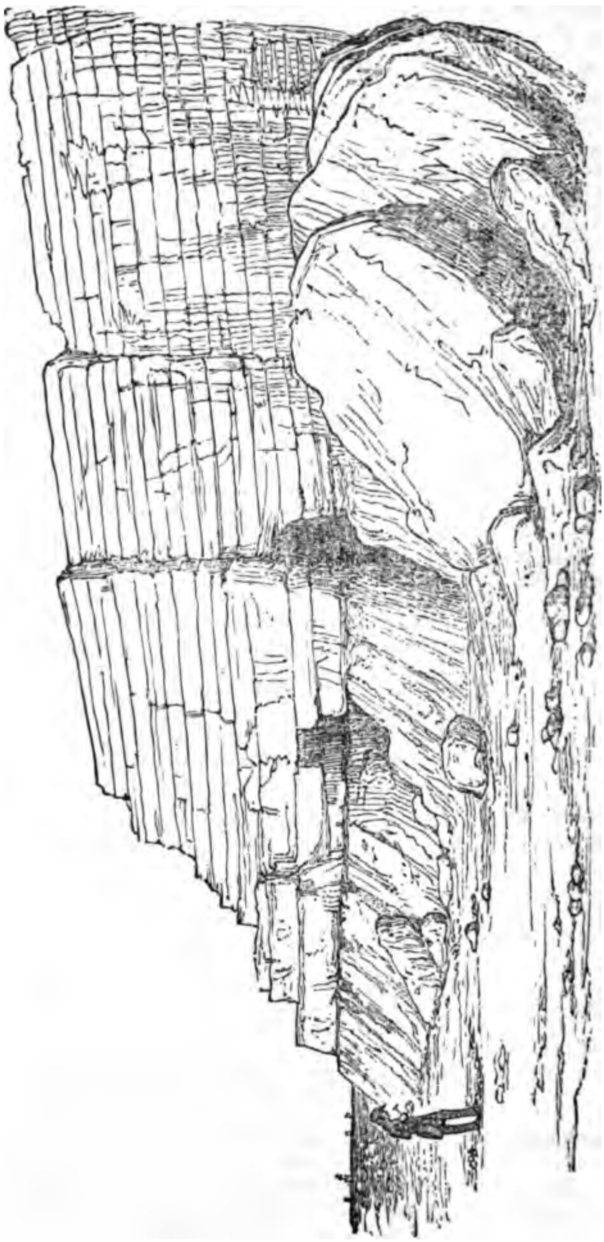
From this point we are enabled again to trace the beds upwards from the Sutton Beds to the ordinary Lower Lias; for although there is another fault that traverses the cliffs in an oblique direction, with a downthrow of about 8 or 9 feet on the west or south-west, yet we are at no loss in comparing the beds on either side of this displacement. The beds adjoining the fault present a massive and wall-like appearance, and some of the higher layers of the Southerndown Series present, where weathered, a curiously ragged, cavernous, and crinkly appearance, standing out in marked contrast from the softer earthy limestones and marls of the Lower Lias above them. (See Fig. 45, p. 101.)

*Section of the Cliffs from below the Flag Staff, Dunraven, to the cavern near the Witches Point.*

| | | | |
|---|---|---|---|
| Zone of *Ammonites Bucklandi*, &c. | Hard limestones, much jointed, and dark bluish-grey and blue-black shales, with *Gryphæa arcuata, Pholadomya ambigua, P. glabra.* | | |
| | Irregular and nodular pale earthy limestones, dark shales and marls, with *Ammonites angulatus*, Gasteropods, *Gryphæa arcuata, Lima gigantea, Unicardium cardioides.* (Here and there we find bands crowded with *G. arcuata.*) | | |
| Southerndown Series. | Hard and somewhat irregular bluish-grey limestones, with sparry veins, shaly beds, fucoidal markings, and occasional fragments of Carboniferous Limestone. *Lima gigantea, L. tuberculata, Ostrea* - - | 5 | 9 |
| | Hard and irregular grey limestones with little or no shale, with sparry veins, and occasional fragments of Carboniferons Limestone - - - - - - | 4 | 0 |
| | Compact grey limestones, with shaly layers: conglomeratic in places. *Ostrea liassica, O. multicostata, Lima gigantea*, spines of Echini, lignite - - - - - - | 4 | 0 |
| Sutton Series. | Hard compact pale-grey and bluish-grey limestones passing in places into a bed like Sutton Stone. *Pecten suttonensis, Ostrea multicostata* - - - - - | 6 | 0 |
| | Hard bluish-grey and compact limestones, conglomeratic and brecciated: massive beds. *Pecten suttonensis* - - - - | 7 | 6 |
| | Compact bluish-grey limestones, wedge-bedded in places - - - - - | 5 | 7 |
| | Compact blue limestones, brecciated in places; passing down into pale-grey brecciated limestone, like Sutton Stone. Shelly in places - - - - - - - | 5 | 0 |
| | Buff, pale grey, and bluish-grey limestones, passing down into white conglomerate About | 15 | 0 |

Fig. 47.

*Section near Dunraven Castle, Glamorganshire.* (De la Beche.)



*b.* Lower Lias (Sutton Stone, &c.) resting on Carboniferous Limestone.

It will be noted that beneath the ordinary limestones of the Lower Lias, we come to, first, a series of hard and more or less conglomeratic limestones that yield *Lima gigantea*, *L. tuberculata*, and other fossils. These are from 12 to 14 feet thick. They rest on a series of bluish-grey and pale grey limestones, more massive in appearance, that pass down gradually into the white conglomerate. In the upper part of this lower series, which is mainly bluish in colour, we may note the horizontal change of a compact blue limestone into pale-grey stone of the character of Sutton Stone, showing that the test of colour is one not to be entirely depended upon. This moreover is shown by the fact that the lowest bed of conglomerate, beneath the white Sutton Stone and conglomerate, is here and there decidedly blue. Moreover, some of the compact blue limestones yielding *Pecten suttonensis*, present characters resembling the highest beds noted in the section at Pant-y-Slade, beds which there and elsewhere along the coast, form a sort of passage from the white Sutton Stone upwards into the blue conglomeratic Southerndown Beds.

It is clear that wherever the base of the conglomeratic series is exposed, we find the white Sutton Stone and conglomerate (of varying thickness) resting on the Carboniferous Limestone. No attempt is made to correlate particular beds in the Southerndown Series of Dunraven with those under Southerndown, because of the blending of these divisions, and the absence of any definitely marked lithological or palæontological horizons.

Undoubtedly the pale creamy and white colour of the Sutton Stone and conglomerate, has led to the supposition that the beds represent the White Lias. In texture however the Sutton Stone differs very much from that rock. It should moreover be noted, that at Penarth the White Lias is represented mainly by grey shaly marls, 12 feet or more in thickness, and does not exhibit a mass of compact white limestones such as we find in Somersetshire. Again at the Stormy Cement Works, between Bridgend and Pyle, the White Lias is but feebly developed, and its probable representative is overlaid by a thin bed of conglomerate that occurs at the base of the Lower Lias. In other localities in this district, as observed by Bristow, the Rhætic Beds are exhibited in close proximity to the conglomeratic Lias. Bearing in mind the fact that in places the Rhætic Beds merge almost imperceptibly into the Lower Lias, it would perhaps be wrong to state dogmatically that no portions of the White Lias are represented in the conglomeratic Lias of South Wales; but we have no evidence that this is the case. No specimens of *Cardium rhæticum*, or *Lima præcursor* have been obtained, but the fossils that do occur include species elsewhere obtained from the basement-beds of the Lower Lias.

Modifications of the Lower Lias have been noticed elsewhere on Broadfield Down and near Shepton Mallet, where the strata rest in similar situations on the Carboniferous Limestone. The beds and the fossils found near Shepton Mallet are so like those

of the Sutton Stone that they could not be distinguished.* This is remarkable, as there is no evidence of any original continuity over the intervening area between beds of this character. The identity is due to the similar origin of the strata, both being largely due to the direct destruction of the Carboniferous Limestone, thus originating as shore-deposits of calcareous mud with which angular detritus was occasionally mixed. In other cases where the Lower Lias rests directly on the Carboniferous Limestone, and at the same time presents its ordinary characters, we may infer that the beds were probably laid down on submarine shelves or platforms of the older rock.

The appearance of the beds in the cliffs of Sutton and Southerndown, changes much, according as the layers come within the influence of the sea,† also where they are much weathered or present joints or fault-faces. Where the Southerndown Beds have been long exposed in the cliffs, they present often a wavy or crinkly appearance which is not exhibited on freshly cut faces; the fact being that softer shaly or marly partings are eroded, and the irregularities of the limestone bands are made more manifest. The Southerndown Beds are more divided in some places than in others by partings of shale. The surfaces of beds just uncovered by the sea, present a smooth appearance, and are blue or bluish-grey in colour, while further on, the platforms, long exposed to the action of the sea, have become brown, rough, and honeycombed. Many beds above and below the chief Gryphæa-bed under Southerndown are "fucoidal" at the base, and also here and there on the surface. There is no definite horizon of Gryphæas, nor of Fucoidal beds, nor even of Gasteropods.

Concerning the organic remains, fossils as a rule are not abundant, and those that are present in the conglomeratic beds of Lias, are difficult to extract, owing to the hardened nature of the rocks. In the lower portions of the Sutton Stone and conglomerate, and especially in the conglomerate exposed, above the Carboniferous Limestone, on the coast near the Black Rocks and Pant-y-Slade, Corals are not uncommon. Some are identical with forms found in the Alpine Trias. The most abundant species is *Elysastræa Fischeri*, which, according to Mr. Tomes, appears "in some places in great masses, the corallites of which, either more or less closely packed, or in disjointed branches, penetrate the stone through and through."‡ Many other species of Corals have been obtained, and although in Mr. Tomes's opinion many of them "must be assigned to a period antecedent to that at which those beds were formed,"§ yet the lithological characters of the rocks, and the absence of clayey sediments, suggest that conditions favourable for coral-growth may have

* See also Moore, Trans. Cardiff Nat. Soc., vol. viii. 1877, p. 56.

† That the induration of the beds is not to any extent due to the action of sea-water, may be judged from the fact that where the ordinary beds of the Lias pass down to the sea-level, they do not exhibit any marked differences.

‡ Quart. Journ. Geol. Soc., vol. xl. p. 368.

§ *Ibid.*, p. 354, and remarks by Prof. Bonney, p. 375.

existed at the time. It is therefore possible that the peculiar character of the Sutton Stone may have been due in part to the waste of coral-beds: the calcareous mud being mixed with the débris of corals. Higher up in the series, where clay-beds come in, we lose the coral-fauna. The Southerndown Beds on the coast contain but few corals, and the two species recorded, are the same as species found in the Sutton Beds.*

The development of coral-life seems to have been local, so that we cannot attempt definite correlations, based on the occurrence of the many species, with beds in other parts of this country, for nowhere else in the basement-beds of the Lower Lias have these organic remains been found in such abundance. Only one species (*Thecosmilia rugosa*) has been recorded from both White Lias and Sutton Stone.

The evidence of the Ammonites is important. Moore indeed included *A. angulatus* in his list of Sutton Stone fossils, but in his section of the strata he notes the occurrence of this species on top of this stone—at least 18 feet 3 inches from its base;† and it is necessary to bear in mind the varying thickness of the beds where they rest in the hollows of the Carboniferous Limestone. Of the two species recorded from the Sutton Series by Tawney, the one named *A. suttonensis* (a form which, according to Prof. Tate‡, is allied to *A. Johnstoni*) was found about 20 feet above the base of the series, both at Dunraven and at the Sutton quarries; while the fragment named *A. dunravenensis* was found about 30 feet above the base of the Sutton Series at Dunraven. We have therefore no actual record of the discovery of an Ammonite in the main mass of the Sutton Stone itself. In many places, however, *Ammonites planorbis*, which characterizes the lowest zone of the Lias, is not found in the bottom-beds; and these have in places been separated under the name of Ostrea Beds, being conspicuous for the prevalence of *Ostrea liassica*.

The above-mentioned Ammonites, however, evidently occur in the beds which shade off from the white Sutton Stone and conglomerate into the bluish grey Southerndown series, and thus confirm the view that the Sutton and Southerndown Beds constitute one palæontological series.

The bed with Gasteropods, that occurs at the base of the ordinary beds of Lias at Dunraven, may correspond with that marked as the top of the Southerndown Beds under Southerndown. There are, however, at least three distinct bands of limestone in the Southerndown Series that yield Gasteropods. The more prominent bed, about 1 foot thick, occurs about 18 inches below the highest conglomeratic bed (top of Southerndown Series) under Southerndown. It is a greyish limestone containing conglomeratic seams, and is well seen in ledges on the foreshore, becoming darker and rougher in appearance away from the cliffs. It has been planed off at somewhat different levels and

* See Duncan, Quart. Journ. Geol. Soc., vol. xxii. p. 15.

† Quart. Journ. Geol. Soc., vol. xxiii. pp. 526, 530; see also notes by Sir W. V. Guise, Proc. Cottesw. Club, vol. iv. p. 109; and *Ibid.*, p. 84.

‡ Quart. Journ. Geol. Soc., vol. xxiii. p. 309.

inclinations. Tawney noted a bed with a great number of large specimens of *Chemnitzia*, about 16 feet from the top of the beds which he grouped with the Southerndown Series: his description well applies to the bed above noted, and as he remarks, it is not possible to extract specimens, owing to the toughness of the limestone.*

*Pecten suttonensis* of Tawney, which is one of the most abundant fossils in the Sutton Stone, was regarded by Moore as the *Pecten Pollux* of d'Orbigny, while Tate considered it to be the same as *P. valoniensis*, Defrance. It is a somewhat variable form. It occurs in the beds at Shepton Mallet and also in the peculiar cherty modifications of the Lower Lias at Harptree Hill. At the last-named locality this species occurs together with *Ostrea multicostata* and *Cardinia suttonensis*, two of the most abundant Sutton Stone fossils, and in the same beds at Harptree there occur *Ammonites planorbis* and *A. Johnstoni* (*torus*), furnishing strong corroborative evidence that the Sutton Stone should be included in the zone of *Ammonites planorbis*.† *A. Johnstoni* has lately been found in beds like the Sutton Stone, at Shepton Mallet. (See p. 88.)

From the published lists of fossils it is difficult to decide what were the precise horizons of all the species. Thus Tawney has given lists from the Sutton and Southerndown Series at various localities; Prof. Tate has given a list of fossils from the Sutton Stone, with a revision of Tawney's species; and Moore has done likewise, although his revisions differ in several respects from those of Prof. Tate. Moore has also given lists from the conglomeratic Lias above the Sutton Stone at Southerndown, and lists from Brocastle, &c.‡ So much difference of opinion exists on the identification of some species, that it is best only to give those about which no doubt has been expressed.

The following fossils have been recorded from the Sutton Stone:—

§Ammonites (see p. 111).
Neritopsis exigua.
Patella.
§Pleurotomaria.
Trochus.
§Cardinia suttonensis.
§Gryphæa.
§Hinnites.
§Lima hettangiensis.
§—— tuberculata.
Ostrea irregularis.
§—— multicostata.
§Pecten suttonensis.
§Plicatula intusstriata.
§Astrocœnia (Stylastræa) gibbosa.
—— reptans.
Cyathocœnia incrustans.
§Elysastræa Fischeri.
Montlivaltia.
Rhabdophyllia recondita.
Thecosmilia mirabilis.
—— rugosa.
—— suttonensis.

* Quart. Journ. Geol. Soc., vol. xxii. pp. 75, 76.

† Geol. East Somerset (Geol. Survey), p. 108. See also Moore, Quart. Journ. Geol. Soc., vol. xxiii. p. 492. W. W. Stoddart noted the occurrence of Sutton Stone fossils in the Zone of *Ammonites planorbis* of the neighbourhood of Bristol, but unfortunately he included the White Lias in that zone. Quart. Journ. Geol. Soc., vol. xxiv. p. 203.

‡ Tawney, *Ibid.*, vol. xxii. p. 79; Tate, *Ibid.*, vol. xxiii. p. 309; Moore, *Ibid.*, pp. 530, &c.

§ Specimens so marked have been obtained by myself, and identified by Messrs. Sharman and Newton.

The following species have been recorded from the Southerndown Series:—

| | |
|---|---|
| Ammonites angulatus. | Lima gigantea. |
| Belemnites acutus. | —— tuberculata. |
| Cerithium nodulosum. | Ostrea liassica. |
| Littorina (?) clathrata. | —— multicostata (arietis). |
| Cardinia. | Pecten suttonensis. |
| Gryphæa arcuata. | Plicatula intusstriata. |
| Lima duplicata. | Echini spines. |

At Brocastle again, there is a rich Coral fauna, containing in fact more species than have been found in the Sutton Stone, although a certain number are common to the two deposits. From this locality Moore obtained a very rich collection of fossils, but, as he remarks, most of these proved to be new, and therefore they afford but little evidence for correlating the beds with other zones in this country. However, the presence of *Gryphæa arcuata*, *Lima gigantea*, *Ostrea liassica*, together with several species of *Cardinia*, recorded by Moore, suggest an early stage of the Lower Lias, and agree generally with his grouping of the beds in the zone of *Ammonites angulatus*, a position also assigned to them on the evidence of the Corals.* Mr. Tomes has expressed the opinion that the Brocastle bed has been to some extent re-assorted, and this is not improbable:† undoubted evidence of the reconstruction of beds is met with in the Lower Lias of the Radstock district. Among the Corals (which have been worked out mainly by Prof. Duncan) are species of *Astrocænia* (*Stylastræa*), *Isastræa*, *Montlivaltia*, *Thecosmilia*, &c.

The old quarry of Brocastle, from which Moore obtained his Liassic fossils and to which reference has been made by several geologists, is situated on the road from Corntown to Cowbridge, east of the buildings known as Longland, on the north side of the road, and a short distance (about ⅜ of a mile) west of Brocastle.‡ The quarry is practically disused, and the conglomeratic beds of Lias are mostly obscured. It is however possible to trace these beds abutting irregularly against the Carboniferous Limestone, as represented by Moore. The older rock is a dark blue crystalline and compact limestone, containing Spirifers and Encrinites. The Lias beds comprise greyish-brown granular limestones, and conglomeratic layers having a matrix of pale and compact limestone. Cherty masses here and there occur in the weathered soil on top of the Carboniferous Limestone.

West of Longland, about 8 feet of coarse pale grey granular and brecciated limestones have been opened up by the roadside, and at the lime-kiln to the south, beds of conglomeratic Lias abut against the Carboniferous Limestone. The Lias near Cowbridge was said by Buckland to be oolitic,§ but I have not obtained any

* Moore, Quart. Journ. Geol. Soc., vol. xxiii. p. 521; Duncan, *Ibid.*, p. 17. See also Rev. H. H. Winwood, Proc. Bath Nat. Hist. Club, vol. vi. p. 218.
† Quart. Journ. Geol. Soc., vol. xl. p. 357.
‡ Moore, Quart. Journ. Geol. Soc., vol. xxiii. p. 521.
§ Murchison, Trans. Geol. Soc., Ser. 2, vol. ii. p. 362.

specimens showing this structure; he evidently referred to iron-shot beds, such as occur in Somersetshire near the Mendip Hills. (See p. 127.)

Near Langan, the conglomeratic beds of Lias spread over a large area and are based upon the sands and shales of the Rhætic Series, as pointed out by Bristow.* According to Moore a sinking at Langan Lead-mine proved the following beds:—†

| | FT. | IN. |
|---|---|---|
| Dense limestones with thin intervening beds of marl, regularly bedded but finely conglomeratic - - Sutton Stone - - - - - - - Unstratified conglomerates [? base of Sutton Series] - | 150 | 0 |

This great thickness of strata may be compared with that in the ravine of Pant-y-Slade, previously mentioned (p. 100).

At St. Mary Hill Common, on the south side, west of Tyrmynnyd, the Sutton Stone has been worked. According to Bristow the beds are slightly conglomeratic, containing fragments of black chert, small pebbles of white quartz, and specks of galena. The following species were obtained:—

| | |
|---|---|
| Cardinia suttonensis. | Ostrea liassica. |
| Lima. | Pinna. |
| Modiola. | Pecten suttonensis. |

The following section was exhibited at the Cement-works on Stormy Down:—

| | | FT. | IN. |
|---|---|---|---|
| Lower Lias. Zone of *Ammonites planorbis.* | Brown clay. | | |
| | Hard compact blue limestones and shales, with *Unicardium*, &c. - - - - - | 3 | 6 |
| | Even beds of shaly limestone and shales - - | 2 | 0 |
| | Dark blue shaly limestones, with near base, beds of blue limestone and shale containing *Ostrea liassica* and *Modiola minima* - - - about | 18 | 0 |
| | Conglomeratic Bed: pale grey and bluish brecciated and shelly limestone - - - about | 0 | 10 |
| Rhætic Beds. | Limestone-shales - - - - - - | 0 | 8 |
| | Hard compact limestone (like Sun bed) - - | 0 | 10 |
| | Shaly parting. | | |
| | Hard compact and rather shaly limestone - - | 0 | 8 |
| | Black shales with thin bands of limestone, *Pecten valoniensis* - - - - - - | 1 | 0 |
| | Grey and greenish marls with hard nodules (formerly used for cement) seen to depth of - - | 3 | 6 |

Bristow, who regarded the conglomerate as the attenuated representative of the Sutton Series, noted its thickness as 2 feet, and described the bed as a "hard, siliceous, and shelly blue conglomerate."‡ Mr. Tomes describes the bed as from 2 to 3 feet thick, and as in all respects like the "Guinea-bed" of Binton in Warwickshire, a bed which he regards as the equivalent of the White Lias.§ It may be remarked, however, that a conglomeratic

* Quart. Journ. Geol. Soc., vol. xxiii. p. 204.
† *Ibid.*, p. 533; Tawney, *Ibid.*, vol. xxii. p. 74. See also Tomes, *Ibid.*, vol. xl. p. 361.
‡ *Ibid.*, vol. xxiii. p. 204.
§ *Ibid.*, vol. xl. pp. 358, 359; see also Lucy, Proc. Cotteswold Club, vol. viii. p. 256.

band, suggesting a local change in conditions, should be grouped rather with the overlying than with the underlying beds, and hence we need not hesitate to place it and the Sutton Stone also in the Lower Lias. Moreover the "Guinea-bed" (as mentioned p. 151). appears to be a remanié bed, containing Lower Lias as well as Rhætic fossils, and therefore of the age of the later remains.

From the Lower Lias here, I obtained *Ostrea irregularis*, and poor specimens, identified somewhat doubtfully with *Ammonites Johnstoni* and *Pholadomya glabra*. Moore recorded *Am. planorbis, Lima gigantea, L. tuberculata, Ostrea multicostata (arietis)*, and *Pecten Pollux (suttonensis)*.* These fossils compare well with the beds at Sutton and Southerndown.

Blue Lias Lime (for building-purposes, &c.) is now made from the shaly limestones of the Lower Lias; and Carboniferous Limestone is brought for the preparation of "white lime" (for agricultural purposes).

The ordinary beds of Lower Lias above the Southerndown Series at Dunraven, have yielded the following species :—

| | |
|---|---|
| †Ammonites angulatus. | Lima duplicata. |
| †—— Bucklandi. | —— gigantea. |
| †—— Conybearei. | —— Hermanni. |
| †—— laqueolus? | †Ostrea multicostata (arietis). |
| —— semicostatus. | †Pholadomya ambigua. |
| Belemnites acutus. | †—— glabra. |
| Cerithium. | †Unicardium cardioides. |
| †Turritella (cast). | Rhynchonella calcicosta. |
| †Gryphæa arcuata. | Pentacrinus tuberculatus. |

From Dunraven onwards to Aberthaw, the coast is bounded by cliffs exhibiting the blue and brown argillaceous limestones, shales, and marls that overlie the conglomeratic Lias of Southerndown. On the east side of the Dunraven headland, the conglomeratic beds dip away beneath the beach, being repeated for a short distance by the oblique fault (before mentioned, p. 107), and by another fault a little further on: beyond which they are not again seen along the coast-sections.

These cliffs exhibit, perhaps, the finest exposure of the Lower Lias Limestones in this country. We have not the complete sequence of Lias visible at Lyme Regis; but here in South Wales the zones of *Ammonites angulatus* and *A. Bucklandi* (taken together) are much more fully and continuously exposed. It is true that 14 miles of cliffs, showing the same set of beds, dislocated here and there by faults, seem a little monotonous; and as fossils are neither very varied nor very abundant, we cannot wonder that the cliffs for the greater part of the distance are but little visited by the geologist. The beds must attain a thickness of quite 200 feet, and for great part of the way the limestones stand out also in ledges and platforms along the foreshore, so that our progress along these natural pavements is a very happy one,

* Quart. Journ. Geol. Soc., vol. xxiii. p. 520.
† Species obtained by myself, and identified by Messrs. Sharman and Newton: some of these and other species are recorded by Moore.

excepting where it is diversified by faults that modify the strike of the ledges, or by heaps of boulder-shingle that lie here and there on the surfaces of the platforms.

The following general sequence is shown: the upper beds being more jointed and open, springs are thrown out at their junction with the bluer beds:—

Zone of *Ammonites Bucklandi*, &c.
- Yellowish argillaceous limestones; about 55 bands, on the whole thicker than the beds below and with less clay—the limestones here and there exhibiting rhomboidal jointing.*
- Bluish-grey limestones; about 80 comparatively thin and on the whole irregular bands, alternating with thin clays, shales, or marls.

Southerndown Series, &c.

The lower division attains a thickness of about 80 feet estimated from the top of the conglomeratic series; and in the first cliff beyond the angle formed by the Dunraven headland, the lower beds are shown to a height of about 70 feet, and the upper occupy about 50 feet above. The cliffs between the gullies of Cwm-mawr and Cwm-bach, rise to a height of 200 feet, so that the limestone-series here exceeds that thickness, though not perhaps to any great extent. We do not however notice any beds in the cliffs as far as Aberthaw, that indicate any other divisions of the Lower Lias, and judging by the fossils, the beds belong to the zones of *Ammonites angulatus*, *A. Bucklandi*, and *A. semicostatus*, and mainly to that of *A. Bucklandi*.

On the whole the beds are tolerably flat, but with a general inclination (interrupted by a gentle anticlinal) towards Nash Point. Approaching this point, a thick mass of limestones appears on the top of the yellow beds in the cliffs, forming a conspicuous band as at Southerndown, and this caps the buttress of Nash Point. Here, then, the cliff is formed of a thick mass of limestones, resting on tolerably thick beds of limestone, bluish and yellowish, and these again on bluish limestones, on the whole even-bedded with here and there crinkly layers and thin partings of shale. The limestones form thick ledges and pavements of rock, varying in direction with the inclination of the beds, and the changes produced here and there by faults. *Gryphæa arcuata*, *Lima gigantea*, and *Ostrea*, occur, often in clusters, together with *Pentacrinus*, small Ammonites and occasionally lignite. (See p. 43.) *Pholadomya* appears not uncommon in the higher jointed beds, fallen masses of which lie on the beach.

The cliffs below the Nash lighthouses, show the thick mass of limestones towards the upper portion of the cliffs, and this is let down to lower levels here and there by faults which thus counteract the influence of the dip. In one instance, not far from Dunraven, a small fault, which displaced the upper beds 2 or 3 feet, was lost towards the base of the cliff, the layers of limestone being just

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* These beds are very similar in character to the Black Limestone locally known as "Aberdo Limestone," in the upper part of the Carboniferous Limestone of Flintshire. A. Strahan, Geol. Rhyl (Mem. Geol. Surv., Sheet 79, N.W.), pp. 15, 16.

separated, then simply bent, and finally no appearance of disturbance was visible. (See Fig 48.) I have seen similar faults in the Purbeck Beds near Swanage. They appear to be due to irregular compression of the beds, and not to the effects of landslips.

FIG. 48.

*Section of Lower Lias, east of Dunraven Castle, Glamorganshire.*

Immediately east and west of St. Donat's Point, the beds are somewhat faulted and tumbled. There is however no great displacement, and the ledges display *Gryphæa arcuata*, *Lima gigantea*, *Ammonites Bucklandi*, and lignite. From the higher beds I obtained *Am. Conybearei.* There is a considerable accumulation of coarse boulder-shingle here, and large blocks are taken away for building-purposes, and occasionally to be burnt for lime. Some of the beds exhibit fucoidal markings.

The beds south of Llantwit-Major are much jointed; in fact the beds showing rhomboidal jointing come down to the beach, and the blocks are worked off by the sea in huge masses. These are readily broken up and rounded, so that the ledges of rock are in many places irregularly covered by accumulations of boulder-shingle. From Llantwit to Stout Point the beds are tolerably level and unbroken—the highest part of the cliffs being 146 feet. There is a slight seaward dip, and this continues towards Summerhouse Point, and has produced cliffs that overhang in places. A short distance east of the Camp, the cliff ends, the last beds seen here being 8 or 10 feet of jointed limestones and clays.

From a short distance east of Summerhouse Point to the east of the River Daw, at East Aberthaw, there are no cliffs, the coast being bordered by Alluvial flats, hillocks of Blown Sand and a high beach of boulder-shingle. It is this shingle, composed of rolled limestone derived from the cliffs further west, that has furnished and still furnishes the celebrated Aberthaw lime. All the "lime" shipped, goes away in the form of pebbles (3 or 4 inches in diameter), and those are reckoned the best that are taken between high- and low-water mark, where washed by the sea. The trade has of late years considerably declined, in fact, since the introduction of railways, the lime from places inland has come more and more into use: but I was informed that 50 or 60 years ago (1827–1837) there were sometimes twenty vessels in the "Port," that had come to take away the stone for lime.

It is curious that the stones gathered from the higher part of the beach where they are sun-dried, are said to be not so good for hydraulic lime; but they are burnt for local purposes at the Lime-kiln near Ocean House, West Aberthaw, where "lump lime" and "ground lime" are prepared.

East of the River Daw, by Pleasant harbour, the platforms of rock contain *Gryphæa arcuata*, and *Lima gigantea*. The cliffs for some distance show hard blue limestones in tolerably thick beds, dipping gently eastwards, and yielding the same fossils together with Ammonites.

At Bridgend the limestones of the Lower Lias have been extensively quarried for building-stone and for Blue Lias lime, which has been put on the market under the name of "Aberthaw lime." The railway-cutting also shows fine sections of the beds, and these were described in detail by Charles Moore, who recorded an alternation of 476 beds of limestone and marl. The lower portion of the series is worked in the quarry, but we do not see the base of the Lias; blue earthy limestones were the lowest beds to be seen, and they are overlaid by compact and earthy bluish-grey and yellowish limestones. Altogether upwards of 76 beds of limestone were exposed in the quarry, for the most part in thick beds with comparatively little clay. The fossils which I obtained, included *Gryphæa arcuata* (and broad varieties), *Ostrea irregularis, Lima gigantea* (large specimens), *Pholadomya ambigua, Homomya, Unicardium cardioides,* and *Pleurotomaria*. By the entrance to the quarry from the railway, the Lias contains lenticular nodules of chert or siliceous limestone, in which Dr. Hinde (to whom I sent specimens) found rod-like sponge-spicules. *Ammonites Bucklandi* occurred here, and I obtained also a large specimen of *Cerithium nodulosum* at the base of the railway-cutting.*

Moore published a list of the fossils obtained by him, including *Ammonites angulatus, A. Conybearei,* and (in the higher beds) *A. semicostatus* and *A. sauzeanus*.† He also noted a number of Gasteropoda. The beds correspond with those seen in the cliffs between Dunraven and Aberthaw, and, like them, include portions of the zone of *A. angulatus*, the zone of *A. Bucklandi*, and that of *A. semicostatus*.

Turning to the borders of the Bristol Channel and the Severn, we find several tracts of Lias. These show that the main portion of the estuary must have been originally excavated through the Lower Lias, the now isolated tracts of which may, in comparatively recent geological times, have been connected with the main mass of Lias at Gloucester, and with the portions preserved at Aberthaw on the north and at Watchet on the south of the Bristol Channel. In these areas we have seldom preserved any beds newer than the zone of *Ammonites semicostatus*, excepting in such a locality as Brent Knoll.

* The fossils were named by Messrs. Sharman and Newton.
† Quart. Journ. Geol. Soc., vol. xxii., pp. 513–517.

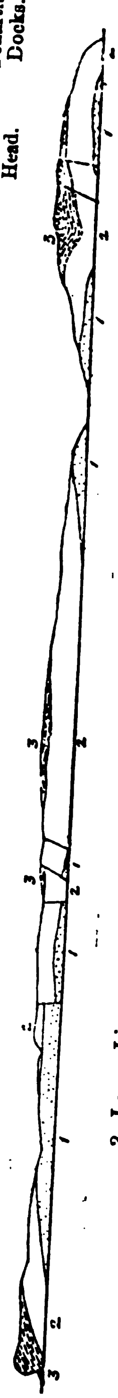
At Penarth there is some difficulty in fixing the precise boundary between the Lower Lias strata and the Rhætic Beds, but where Nature has made no marked line of demarcation, it is perhaps needless for us to be concerned about the matter. The Grey Marls that occur above the Black Shales represent the White Lias of other localities, and, in fact, we find some layers of White Lias in this division at Penarth, together with a band that reminds us of the Cotham Stone. The fossils include species of *Ostrea, Modiola, Pleurophorus,* &c., for the most part poorly preserved, as the fossils usually are in this portion of the Rhætic Series. On top of these marls there is a bed of dark-grey and brown paper-shales, from one to two feet thick, that forms what may be termed the debateable ground between the Rhætic Beds and the Lias. I should prefer to group it with the Lias, because a similar bed is found in many localities on top of the White Lias, and in situations where it clearly belongs to the Lower Lias. At Penarth itself we cannot decide the matter, for the fossils *Ostrea liassica* and *Modiola minima,* are common to the Rhætic Beds and Lower Lias.

Resting on those thin and debateable shales, we find a series of even-bedded argillaceous limestones and clays, yielding the *Ostrea* and *Modiola* in abundance, especially the former, so that they constitute the "Ostrea-beds" of some authorities—here 12 or 15 feet thick. They contain also *Pleuromya crowcombeia.* These merge upwards into similar beds that contain many specimens of *Ammonites planorbis,* together with *A. Belcheri, A. Johnstoni,* and small examples of *Lima gigantea,* so that the mass of the Lias above the Rhætic Beds, for 35 or 40 feet, belongs to the zone of *Ammonites planorbis.* These beds cap the headland of Penarth, and are well shown at Lavernock Point where they dip seaward (see Fig. 49.); but rounding this headland towards the west, we find the limestones paving the foreshore (where they exhibit their fossil treasures) and dipping westwards for a space, when they again rise, forming, in fact, a gentle synclinal. The trough of this is filled with a series of grey marls, not unlike those of the Rhætic Beds, and I was at first much puzzled with them when examining sections on the new railway near Lavernock, and a cutting by the docks north-west of Barry Island. These marls and marly clays, with indurated bands, about 40 feet thick, are overlaid by 25 feet of limestones and clays. Unfortunately the upper part of the cliff west of Lavernock is not very accessible, and, as no fossils rewarded my labours, I could only infer that these marls and overlying limestones belong to the zones of *Ammonites angulatus* and *A. Bucklandi*—zones which are, to some extent, represented at Penarth Headland, and in quarries east of the Penarth dock railway-station; and are so well developed further westwards along the Glamorganshire coast. On the Watchet coast also, the zone of *Am. angulatus* appears to be represented mainly by grey shale and marl. (See p. 93.)

FIG. 49.

*Section from Lavernock to Penarth, Glamorganshire.*

Horizontal Scale about 2¼ inches to a mile. Vertical Scale one inch to about 800 feet.




3. Lower Lias. 2. Rhætic Beds. 1. New Red Marl (Keuper).

Dr Wright has noted the occurrence of *Ammonites Turneri* in the highest beds at Penarth. He also records *Cardinia ovalis*, *Gryphæa arcuata*, and other fossils belonging to the beds above the zone of *A. planorbis*.*

Summarized, the Lower Lias at Penarth and Lavernock is represented by the following strata, above the Rhætic Beds :—

| | | Ft. | In. |
|---|---|---|---|
| Zones of *A. semicostatus*, *A. Bucklandi*, and *A. angulatus*. | Alternations of limestone and clay - about | 60 | 0 |
| | Grey marls with occasional nodules of cement-stone and bands of marly limestone about | 40 | 0 |
| Zone of *A. planorbis*. | Even-bedded limestones and limestone-shales with *Am. planorbis*, &c. - about | 22 | 0 |
| | Even-bedded tough blue marly and shelly limestones, clays, and shales, with *Ostrea liassica*, &c. - - - - | 14 | 0 |
| | Calcareous paper-shales - - 1 0 to | 1 | 0 |
| Rhætic Beds | Band of compact and earthy limestone (impersistent), (probably equivalent to the *Monotis*-bed of Garden Cliff). | | |
| | Bluish micaceous, shales and clays with "race," passing down into marly clay with bands of compact and marly limestone 12 0 to 15 | | |
| | Black shales with *Avicula contorta*, &c. | | |

The Lower Lias has been extensively quarried at Lliswerry (Liswery) east of Newport in Monmouthshire. The beds are worked in part for stone used for building-purposes, but chiefly for lime-burning: Portland cement, and Blue Lias Hydraulic lime being prepared. No agricultural lime is obtained, as the substance prepared, binds too much when put on the land, owing no doubt to its hydraulic properties. Building-lime is made also at a quarry N.E. of Tredegar Park, where the material is worked only for local purposes on the estate.

The principal quarry at Lliswerry showed the following beds:—

| | | Ft. | In. |
|---|---|---|---|
| Lower Lias. Zone of *Ammonites planorbis*. | Bluish-grey and hard blue, mostly irregular, earthy, and shelly limestones; separated by brown clays at the top and by dark blue shales lower down - - - - - | 8 | 6 |
| | More even layers (eight or nine) of earthy limestone with very thin partings of shale - | 8 | 0 |

The total thickness of the Lower Lias at Lliswerry is estimated at 25 feet. The beds yield few fossils, with the exception of *Ostrea liassica* (which is very abundant), and *Lima gigantea*. Saurian bones, including remains of *Plesiosaurus*, were obtained in 1881, by Prof. Sollas, and placed in the Bristol Museum. Mr. J. E. Lee

* Quart. Journ. Geol. Soc., vol. xvi. p. 381; and Lias Ammonites, Palæontogr. Soc., p. 10. See also Vertical Sections, Geol. Survey, Sheet 47; and H. B. Woodward, Proc. Geol. Assoc., vol. x. p. 529; Rep. Brit. Assoc. for 1888, p. 900.

remarked that these beds (which belong to the zone of *Ammonites planorbis*) were known to the quarrymen as "sarpent-stone."*

At the Tredegar quarry we find limetones and clays similar to the beds at Lliswerry, but on a somewhat higher horizon. They yield *Ostrea liassica* and *Lima*, but the best cement-beds lie below the layers that were exposed at the time of my visit in 1888. The total thickness of stone-beds is about 40 feet, according to the lime-burner.

At Gold Cliff, south east of Newport, we find the lowest beds of the Lias, comprising 10 or 12 feet of dark shales and grey argillaceous limestones, resting on the Rhætic Beds. I obtained *Ammonites planorbis*, *Cardinia*, *Gryphæa arcuata*, *Modiola minima*, *Ostrea liassica*, and *Pholadomya*. The name Gold Cliff was derived from the glittering appearance of the iron-pyrites that was formerly to be seen in the black (Rhætic) shales.† The greater portion of the cliff is now walled-up for the protection of the coast.

In the Severn Cliff, east of Chepstow, and north of Beachley, the lowest beds of the Lower Lias (zone of *A. planorbis*) are present above the Rhætic Beds. *Ammonites planorbis*, *A. Johnstoni*, *Ostrea liassica*, and *Lima gigantea* have been recorded.‡

* Note-Book of an Amateur Geologist, 1881, p. 34.
† Buckland and Conybeare, Trans. Geol. Soc., ser. 2, vol. i. p. 305.
‡ Proc. Cotteswold Club, vol. vi. p. 271.

# CHAPTER V.

## LOWER LIAS (*continued*).

### Local Details.

*Harptree and Chewton Mendip.*

North of the Mendips the direction of the Liassic outcrop is very irregular, and straggling outliers extend westwards on to the plateau of Carboniferous Limestone on Broadfield Down.

It may be remarked that the Lias, and also the Rhætic Beds, overlap the New Red Marl in places, so as to repose directly on the Carboniferous Limestone, the Lower Limestone Shales and the Old Red Sandstone in the Mendip Country, and on the borders of the Bristol Coal-field; but there is seldom any evidence to show that these beds anywhere rest directly on the Coal-measures, or even on the Millstone Grit, there being, in nearly all cases, evidence of intervening masses of Red Marl or Dolomitic Conglomerate. The exceptions are near Babington and Holcombe, where the Lower Lias is represented, on the Geological Survey Map, as reposing directly on the Coal-measures; at Doynton, north of Bath, where it rests on the Millstone Grit; and near Emborrow, where it rests probably on the same formation.

A remarkable set of arenaceous and cherty beds of Rhætic and Liassic age, occurs in the neighbourhood of Chewton Mendip, on Harptree and Egar Hills, at East End, Emborrow, and near Binegar.

Attention was directed to them as early as 1819 by Thomas Weaver,* who gave the fullest particulars we have of the strata, but assigned them with doubt, to the age of the cherty beds (of Upper Greensand age) on the Blackdown Hills of Devonshire. A few years later (1823), Buckland and Conybeare† described the cherty beds, noticing the occurrence of Ammonites and other fossils, some of which have been chalcedonized, while others occur in the state of casts. These geologists, however, referred the beds (with hesitation) to the Dolomitic Conglomerate, because somewhat similar (though unfossiliferous) cherty beds are associated with that formation, at Eastwood House, and on the hill above it, near East Harptree, and near Green Down Cottage. During the progress of the Geological Survey the beds were recognized by De la Beche‡ as of Liassic age; and in the re-survey in 1868, the cherty beds of Liassic and Triassic age were separately mapped by myself.§

The cherty Liassic deposit reposes on the Dolomitic Conglomerate, the Carboniferous Limestone, and Old Red Sandstone: and probably also on the Millstone Grit. The strata must in places attain a thickness of at least 30 feet, but in the absence of any continuous section, showing the whole of the beds, this estimate is approximate.

As remarked by Buckland and Conybeare, the high ground above East Harptree "is covered with blocks of the chert, which

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* Trans. Geol. Soc., ser. 2, vol. i. p. 364.

† *Ibid.*, p. 294; Conybeare and Phillips, Geol. England and Wales, p. 304.

‡ Mem. Geol. Survey, vol. i. p. 277.

§ Geol. E. Somerset, &c., p. 105.

appears also in numerous excavations, forming a thick horizontal bed, reposing on ochreous sand. The whole surface is often scarred with deep, conical, and often very extensive hollows, which probably are ancient ochre pits." Weaver mentioned that beds of clay, from 1 to 3 feet thick, and much charged with yellow ochre, were wrought for the sake of that substance (from which a pigment was prepared), by means of pits sunk two or three fathoms in depth. Some of these pits, however, may have been sunk to obtain calamine from the Dolomitic Conglomerate beneath the chert, while others may be natural "pot-holes" or "swallet-holes," due to dissolution of the Carboniferous Limestone. It is difficult in every case to decide the origin of the pits, for most of them are much obscured by a talus of chert and sandstone fragments.

The largest and most instructive pit occurs east of the Harptree Road, about half way between East Harptree and the Castle of Comfort. It is about 60 feet in diameter at the mouth, is funnel-shaped, and about 20 to 30 feet in depth. It is evidently a natural "pot-" or "swallet-hole." The section consists almost entirely of massive bedded chert, occurring in layers of from 1 to 3 feet in thickness, standing out sharply, but sometimes weathering sandy at the exterior, and separated by thin clayey beds an inch or two in thickness. The beds are coated here and there with quartz crystals.

Most of the ochre appears to have been obtained from beds at or near the base of the chert. The chert itself is often of a compact character, and sometimes banded, resembling the rocks termed Hornstone and Woodstone by the older Mineralogists. In other instances the texture is granular. It is of various shades of brown, buff, bluish-grey, and white; and associated with it are beds, described by Weaver as quartzose sandstone. The rock-specimens examined by Mr. Teall, including the granular varieties, consist of chalcedonic silica. Heavy Spar occurs here and there in the joints of the rock.

A number of fossils were collected by R. Gibbs and myself from the chert of Harptree Hill; and in the large pit (before mentioned) fossils were noticed only in the upper beds, and these were extracted with great difficulty. Specimens are more readily to be obtained from loose blocks, or from the walls, where the rock has to some extent decayed and become softer. The following species were identified by Mr. Etheridge* :—

Ammonites planorbis.
—— Johnstoni.
Astarte, sp.
Cardinia suttonensis.
—— sp.
Lima gigantea.
—— pectinata.
—— pectinoides (like L. duplicata).
—— cast of, like L. exaltata.
Modiola minima.
Pleuromya.
Myoconcha psilonoti.
Ostrea liassica.
—— multicostata.
—— sublamellosa.
Pecten Pollux (or suttonensis).
Unicardium.

* Geol. E. Somerset, &c., p. 108. See also Moore, Quart. Journ. Geol. Soc., vol. xxiii. p. 492.

Encrinites occur in some places, as at Emborrow, but these are no doubt derived from the Carboniferous Limestone.

The beds below the chert were well exposed near the cottage at Harptree Hill, in a pit showing hardened reddish-brown micaceous sand with *Pullastra arenicola*. In this neighbourhood I obtained also *Avicula contorta* and *Pecten valoniensis*, thus proving the Rhætic age of the lower beds.*

The precise junction of Rhætic Beds and Lower Lias is not now to be determined, but in the section published by Weaver, he noted a bed of siliceous breccia at the base of the cherty beds and overlying the sands. This breccia is said to contain fragments of sandstone (probably Old Red Sandstone), quartz, &c.† Whether this should be taken as the approximate boundary of Rhætic Beds and Lower Lias, or whether beds of the age of the White Lias are included in the overlying cherty beds, cannot be decided from the evidence before us. All we can say is that the fossils obtained from the cherty beds represent the zone of *Ammonites planorbis*; and it is noteworthy that they include forms characteristic of the Sutton Stone of Glamorganshire. (See p. 112.)

Dr. G. J. Hinde, who has examined the rocks *in situ*, informed me (October 1887) that the chert "seems everywhere to have the same porous structure, and the silica is in peculiar crystalline grains, resembling frosted sugar. The cavities seem, in part at least, to be due to the dissolution and removal of fragments of calcareous organisms; amongst them I can recognise the casts of fluted Echinoderm spines. The silica appears to have infilled the minute interspaces between the calcareous fragments to form a matrix, and subsequently they were dissolved out. After several hours hammering, both at the pit and at the material on the fields, I only found one fragment in which sponge-spicules were present, and this was by the road-side between the Castle of Comfort and the East Harptree pit. I had at first some doubt whether the piece might belong to the Liassic Chert, but I now think it does, for I can find casts of the minute Echinoderm spines, and though the larger part is compact there is a porous portion of the same character as the rest of the Lias Chert. This solitary specimen gives some grounds for the belief that if we could find the Lias Chert unweathered, it would show its derivation from sponge-remains, the same as the Carboniferous Chert. * * * Nevertheless I do not think it would be right to conclude that the Liassic Chert has been derived directly from the sea-water, though there is but scant evidence of its organic origin; for it is quite possible that its present granular crystalline condition may have resulted from the alteration of the organic silica of Sponge-spicules or other siliceous structures. There is a somewhat similar condition of the silica in the Carboniferous (so-called) chert at Bakewell in Derbyshire. * * * I found plentiful traces of spicules in blocks of *Carboniferous* Chert in the roadside-walls between Wells and the Mendips; and curiously enough two fragments of cherty rock, which you had given to Mr. A. Gillett, from the Mendip rocks, showed spicules very distinctly, and it is therefore probable that the Mendip Chert is of the same character as that in the Carboniferous rocks of Yorkshire."

In attempting to account for the origin of this Cherty Lias (1868–71), I was impressed with the fact that, around Green Down Cottage, the Lower Lias and underlying White Lias present their ordinary characters. The Lower Lias there consists of hard argillaceous limestones and clays with *Lima gigantea*, and

* See also Tawney, Quart. Journ. Geol. Soc., vol. xxii. p. 79.

† Some of the Druidical stones of Stanton Drew are blocks that resemble this and other beds belonging to this cherty series.

at the base there is a thin laminated sandy limestone with *Ostrea liassica* in profusion. South of the cross-roads at Egar Hill, Lias limestone occurs, tough and compact, and not unlike Carboniferous Limestone, as are certain beds of the Lias near Shepton Mallet and in South Wales. *Ammonites Johnstoni* was here met with. The Rhætic Sands, before mentioned, occur over the ordinary grey marls, which pass downwards into the red marls of the Keuper.

The alterations therefore are local and abrupt, and it is important to notice that we find these siliceous modifications in both Lias and Trias. The sandy modifications of the Rhætic Beds, above the Grey Marls, are significant, and point to marginal deposits, derived probably from Old Red Sandstone; but we have no evidence to prove that the Lower Lias was here represented by sandy sediments. In any case the beds have undergone alteration. I compared this Cherty Lias with that at Portrush in the N.E. of Ireland, where the argillaceous beds have been metamorphosed into a dark lydian stone by contact with basalt. On the Mendips we have no evidence of eruptive rocks nearer than Downhead. It is, however, possible there may have been some intrusive rock which did not find its way to the surface, but made its influence felt by the agency of heated water. This, in short, is the hypothesis I ventured to advocate; and the fact that the Triassic Beds in the neighbourhood are also of a peculiar cherty nature, lent some support to the notion.* I may add that near Frome the Inferior Oolite, in places, exhibits a very cherty character. De la Beche has called attention to this,† and I shall have occasion to refer to the subject in a subsequent volume.

### *Radstock and Paulton.*

The Lias in the area north of the Mendip Hills around Radstock, Paulton, and Timsbury may be divided as follows:—

| | | Ft. | In. | | Ft. | In. |
|---|---|---|---|---|---|---|
| Lias | Blue clays | 100 | 0 | to | 120 | 0 |
| | Limestone and clays | 7 | 6 | ,, | 24 | 0 |
| Rhætic Beds. | White Lias (the top layer known as the Sun Bed). | | | | | |

The Inferior Oolite in this tract rests directly on the Blue Clays, and there has been some difficulty in fixing their precise age. Do they represent Upper, Middle, and Lower Lias, or portions only of one or more of these formations? The difficulties are mainly due to the rarity of sections, the want of palæontological evidence, and the apparent absence, between Bath and the Mendip Hills, of any prominent beds of Marlstone.

Palæontological evidence, however, shows that in this region the zone of *Ammonites Jamesoni*, and locally that of *A. Henleyi*, are represented, like the lower zones, by one or more bands of limestone; so that as regards the main mass of the Lower Lias, the calcareous beds prevail over the argillaceous. Therefore it

* Geol. Mag., 1871, p. 400.
† Mem. Geol. Survey, vol. i. p. 287.

may be concluded that the mass of the blue clay here belongs to the Middle Lias, and part perhaps to the Upper Lias.

The Lower Lias in the neighbourhood of Radstock presents many remarkable features, to which attention was first called by Charles Moore. The beds exhibit in places a considerable attenuation, while at the same time they are rich in fossils: in this respect resembling the Inferior Oolite of Dorset, where a similar diminution in the thickness of the strata is attended by a great abundance of organic remains.

The sections near Radstock, moreover, exhibit much variation in detail; phosphatized fossils occur at different horizons, and there is evidence of the reconstruction of some layers and the consequent derivation of some of the fossils from earlier stages, so that there is a commingling of species that elsewhere occur in more or less distinct zones. At the same time, the general succession of the zones of life is not disturbed, although the distinctions cannot be always recognized. That there was a paucity, and even absence of sediment, over certain areas may be safely assumed from the features presented by the different sections. Tawney observed that "there really was not sufficient sediment to be the burial ground of distinct zones of life."* The zones overlap one another and vary much in their distribution: for instance, the Spirifer-bed sometimes rests directly on the White Lias, and at others it is separated by some thickness of limestone.

As a rule the lowest beds of the Lower Lias consist of two or three beds of brown gritty limestone, with ferruginous specks; these are from 18 inches to 4 feet thick, they are fossiliferous, and they give rise to a red soil. The beds are known to the quarrymen as "Corn grit."† Higher up there are beds of pale buff or yellowish iron-shot limestone that it is not always easy to distinguish from the Marlstone or Inferior Oolite.‡ This iron-shot character is especially marked in the layers yielding *Ammonites Jamesoni*, and as remarked by Tawney, the little grains of yellow ochre produce an oolitic appearance. A section of this iron-shot rock from Paulton shows no true oolitic structure; the specimen was sent to Mr. A. Strahan and examined by Dr. Hinde, who found that the grains were mostly fragments of Echinoderms.

The identification of the several zones depends entirely on the collection of fossils *in situ* from each individual layer, and as the bands of limestone are often very tough, much labour and patience are needed, for the specimens put aside by the quarrymen cannot be depended upon for this purpose. Representatives of all the zones of the Lower Lias have locally been noticed.

*Spiriferina Walcotti*, which locally is a very abundant fossil, occurs chiefly in a clay-band, belonging to the zone of *A. Bucklandi*. Many of the Brachiopoda recorded, are those

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* Tawney, Proc. Bristol Nat. Soc., ser. 2, vol. i., pp. 172–175.
† Lonsdale, Trans. Geol. Soc., ser. 2, vol. iii. p. 246.
‡ See also Buckland and Conybeare, Trans. Geol. Soc., ser. 2, vol. i. p. 300.

found elsewhere abundantly in the Marlstone; *Gryphæa cymbium* is also a Middle Lias form.

Rolled pieces of Carboniferous Limestone, and occasionally pebbles of quartz, occur in the beds, but they are more remarkable for phosphatic nodules and phosphatized fossils, which occur at different horizons, though not in great abundance. These facts furnish evidence of reconstruction and of pauses in the deposition of the strata. Bristow and myself noticed a limestone, the base of which contained many black irregular and tough calcareous nodules in several of the quarries near Timsbury, Paulton, and Radstock.* At Timsbury this bed occurred 3 ft. 9 in. above the Sun bed, and we obtained *Gryphæa arcuata* in a bed of clay immediately above it. *Ammonites planicosta* occurs at this locality.

The following section at Branch Huish, south-east of Radstock, was noted by E. B. Tawney† :—

| | | Ft. | In. |
|---|---|---|---|
| Upper Lias? | Yellowish-brown clays - - - - | 2 | 6 |
| Middle Lias. | Pale-grey iron-shot limestone, with *Cardinia concinna, Myacites*, &c. - - - | 1 | 6 |
| Lower Lias. | Light yellow iron-shot limestones, with *Ammonites Jamesoni, A. Ibex, A. brevispina, Nautilus, Gryphæa cymbium, Inoceramus ventricosus, Terebratula punctata, Waldheimia numismalis, Rhynchonella tetrahedra*, &c. - | 6 | 0 |
| | Pale marly limestone, with dark phosphatic concretions, *Ammonites raricostatus* phosphatized - - - - - - | 1 | 5 |
| | Pale limestones with clay-partings, *Ammonites planorbis, Lima gigantea*, &c. (Corn grit) - | 4 | 0 |
| Rhætic Beds. | White Lias. | | |

Tawney grouped the beds above the "Corn grit," in this section, with the Middle Lias, in accordance with the classification employed by Dr. Wright; but the fossiliferous beds belong chiefly to the Lower Lias, according to the grouping now adopted. West of Radstock Church, in the Wells road, the Lower Lias limestones are much more thickly developed; and the following section was described by Tawney,‡ with whose notes my own are incorporated :—

| | | | Ft. | In. |
|---|---|---|---|---|
| Lower Lias. | Zones of *Ammonites Bucklandi* and *A. planorbis*. | Grey clay with phosphatic nodules, *Spiriferina Walcotti, Rhynchonella variabilis, Gryphæa arcuata*, &c. - - ; Two thick beds of limestone, separated by grey shaly clay, with *G. arcuata* - | 7 | 0 |
| | | About 30 layers of grey and brown argillaceous limestone, with thin clay-partings, *G. arcuata, Lima gigantea, L. punctata* - - - - - | 18 | 0 |
| | | Thin even beds of fissile sandy limestone and shale (4 or 5 layers), *Ostrea liassica, Modiola minima* (Corn grit) - | 3 | 0 |
| Rhætic Beds. | | White Lias. | | |

* These are also noticed by Lonsdale, Trans. Geol. Soc., ser. 2, vol. iii. p. 246.
† Proc. Bristol Nat. Soc., ser. 2, vol. i. p. 186.
‡ Proc. Bristol Nat. Soc., ser. 2, vol. i. p. 170. See also R. Tate, Quart. Journ. Geol. Soc., vol. xxxi. p. 495.

The layers of Corn grit are used for paving; the limestones above are said to make the best lime in the district. Tawney obtained a specimen of *Ammonites planorbis* at this quarry, probably from the lower beds.

The Lower Lias was well exposed in cuttings along the Midland Railway between Radstock and Wellow. South-east of Shoscomb the Sun bed was seen at the base of the Lias. The limestones of the Lower Lias, which are rather disturbed in places, are rich in fossils. The Spirifer-bank, as was pointed out to me by Moore, occurs in the upper part of the Limestone Series capped by blue clay, which is the Foraminifera-zone. Towards Wellow, cuttings in blue clay have been made, and this is apparently unfossiliferous. Bands of earthy limestone occur here and there in the clay, which is micaceous, and in part of Middle Lias age. Upper Lias was identified in places by Moore, and the beds are capped by Inferior Oolite.

At Stoney Littleton the following section was to be seen:—

| | | Ft. | In. |
|---|---|---|---|
| Lower Lias. | Clay, with *Spiriferina Walcotti* and *S. rostrata*, *Rhynchonella variabilis*, *Belemnites*, *Ammonites Maugenesti*, *A. raricostatus*, *A. semicostatus?* Fossils in many cases phosphatized | 1 | 0 |
| | Thick limestone, with many specimens of *Gryphæa arcuata* at top. *Amm. Bucklandi* | 2 | 0 |
| | Rubbly limestone and clay. *Lima gigantea*, *Ostrea* | 5 | 0 |
| | Stone with clay-partings. *L. gigantea* | 7 | 0 |
| | Thinner beds of limestone and brown shale (Corn grit) | 2 | 0 |
| Rhætic Beds. | White Lias (ferruginous stains on joints). | | |

I also obtained *Lima hettangiensis*, *L. succincta*, *Pholadomya glabra*, and *Unicardium cardioides*.

Near Stoney Littleton large blocks of sandy iron-shot limestone were found imbedded in the blue clay at the base of the railway-cutting. They yielded *Pecten lunularis* (*liasinus*), *Ammonites Ibex*, *A. Maugenesti*, and numerous *Belemnites*: thus indicating the zone of *Am. Jamesoni*.

Proceeding north of Radstock towards the Clan Down coal-works, there are several quarries, which however are not much worked at present, and it is difficult to note the sequence of the beds down to the White Lias. The sections have been recorded in detail by Tawney * and Prof. Tate.† *Ammonites Jamesoni*. *A. Henleyi*, and other species occur in the upper beds; lower down *A. subplanicosta* has been met with. I obtained *Ammonites Ibex*, *A. Maugenesti*, *A. raricostatus*, *A. semicostatus*, *A. Valdani*, *Pleurotomaria*, *Gryphæa*, *Lima Hermanni*, *Pholadomya ambigua*, *Rhynchonella variabilis*, *Spiriferina Walcotti*, and *Terebratula punctata*: species indentified by Messrs. Sharman and Newton.

Further on at Bowldish, a quarry north of Welton, and immediately south-west of the cross-roads between Clan Down and Paulton, showed the following section, which I visited in company with the Rev. H. H. Winwood:—

* Proc. Bristol Nat. Soc., ser. 2, vol. i. pp. 172–177.

† Quart. Journ. Geol. Soc., vol. xxxi. pp. 495, 497, 500, &c.

| | | | Ft. | In. |
|---|---|---|---|---|
| Lower Lias. | Zone of A. armatus. | Grey limestone, with iron-shot grains. [Noticed by Tawney, who recorded from it *A. armatus*, *A. raricostatus* (probably derived), *Terebratula punctata*, *Rhynchonella variabilis*, &c.] | 0 | 8 |
| | Zone of A. raricostatus. | Clays with a bed of nodular limestone [*A. raricostatus*], *Nautilus* [*Belemnites penicillatus*, *Gryphæa cymbium*], *Spiriferina Walcotti*, *Nulliporites*? | 2 | 0 |
| | Zone of A. obtusus? | Interrupted bed of limestone—large Ammonite. | | |
| | Zones of A. Bucklandi and A. planorbis. | Clay, Spirifer-bank, with *S. Walcotti* very abundant, *Gryphæa arcuata*, *Ammonites bisulcatus*, [*A. Bucklandi*, *A. raricostatus*, *A. sauzeanus*, *T. punctata*, *R. variabilis*]. Phosphatic concretions and phosphatized fossils | 3 | 0 |
| | | Limestones, with phosphatic concretions near top. [*A. sauzeanus*], *A. Bucklandi*, *Lima gigantea*, *Gryphæa arcuata*, *Ostrea liassica*, &c. | 4 | 0 |
| Rhætic Beds. | | White Lias. | | |

The species included in brackets, were recorded by Tawney.* In addition to those mentioned, I obtained *Ammonites Jamesoni*, *Pholadomya ambigua*, and *Pecten Pollux*.

Munger quarry, south-east of Paulton, is situated south of the Coal-works (on the Lias), and between the two roads. It has, however, long been disused, and only a few of the upper beds were exposed to view in 1886, when I visited the locality under the guidance of the Rev. H. H. Winwood. The section was first described by Moore,† who obtained many fossils, while additional species have been recorded by Tawney‡ and Tate.§ These include *Ammonites Henleyi*, *A. Jamesoni*, *A. latæcosta*, *A. fimbriatus*, *A. Ibex*, *A. Maugenesti*, *A. Valdani*, *A. raricostatus*, *A. Turneri*, *A. Johnstoni*, Belemnites (several species), &c. I obtained *Ammonites nitescens* (a Middle Lias form), and *Lima succincta*, from the upper beds, which no doubt represent the Middle Lias. A sandy bed with *Spiriferina Walcotti*, *Gryphæa arcuata*, and Belemnites, occurred at the base, resting on the White Lias.

Another section in this neighbourhood, "about one mile south-east of Paulton," was noted in 1867 by Bristow and myself; it showed the following beds ‖ :—

| | | Fp. | In. |
|---|---|---|---|
| Lower Lias. | Soil and rubble of limestone and clay, with *Ammonites*, *Belemnites*, and *Rhynchonella* - about | 4 | 6 |
| | Limestone, nodular at base | 1 | 0 |
| | Nodular and clayey beds, with *Belemnites*, *Gryphæa arcuata*, *Pholadomya*, *Pleurotomaria*, *Waldheimia numismalis* | 1 | 0 |
| | Limestones, with *Belemnites*, *Gryphæa arcuata*, and *Spiriferina Walcotti* | 3 | 0 |
| Rhætic Beds. | White Lias. | | |

* Proc. Bristol Nat. Soc., ser. 2, vol. i. pp. 172–175.
† Quart. Journ. Geol. Soc., vol. xxiii. p. 474.
‡ Proc. Bristol Nat. Soc., ser. 2, vol. i. p. 178: and specimens in the Bristol Museum.
§ Quart. Journ. Geol. Soc., vol. xxxi. p. 500.
‖ See also Vertical Sections, Geol. Survey, Sheet 46, No. 13.

A brickyard to the north of Munger quarry, showed about 10 feet of blue and brown clays, with nodules of argillaceous ironstone and septaria, resting on 8 feet of dark blue clay; beds regarded by Tawney as Upper Lias. (*See* p. 210.)

Phyllis Hill quarry is situated a little north-west of Munger quarry, on the road between Paulton and Midsomer Norton. It showed the following section in 1886.* (*See* Fig. 50):—

| | | Ft. In. Ft. In. |
|---|---|---|
| Lower Lias. | D. Irregular shelly limestones, with *Belemnites*, and *Rhynchonella* | 1 6 to 2 0 |
| | C. Dark bluish and pale grey clay, with nodules of limestone, phosphatic concretions, &c. | 0 6 |
| | B. Pale grey earthy limestones, with *Gryphæa arcuata* at the base | 0 4 to 0 8 |
| | A. Clay and sandy marl, sandy at base, with phosphatic nodules, *G. arcuata*, *Pecten lunularis*, large *Pleurotomaria*, *Spiriferina Walcotti*, and Lignite (Dicotyledonous) | 1 0 to 1 6 |
| Rhætic Beds. | Sun bed (with *Gryphæa arcuata* in crevices) | 1 6 to 2 2 |
| | White Lias | 4 6 |

FIG. 50. *Section at Phyllis Hill, Paulton, Somersetshire.*


*b.* Lower Lias. *a.* White Lias (Rhætic Beds).

Among the species I obtained were *A. scipionianus*, *A. semicostatus*, *A. Jamesoni*, *A. bisulcatus*, *A. brevispina*, *Cryptænia solarioides*, *Homomya*, *Cardinia*, *Ostrea*, *Pecten lunularis*, *Lima acuticosta*, *Waldheimia Waterhousei*, *W. numismalis*, *W. cornuta*, and *Rhynchonella rimosa*. These fossils were named by Messrs. Sharman and Newton. Tawney recorded *A. Bucklandi*, *A. sauzeanus*, *A. raricostatus*, *Terebratula punctata*, from bed A., which he groups with the zone of *A. Bucklandi*; from bed B., he noted *A. obtusus* and *A. oxynotus*?; from bed C., *A. raricostatus* (phosphatized), *A. planicosta*, *A. oxynotus*?; and from bed D., *Waldheimia numismalis* and *Pholadomya ambigua*.†

From a quarry north-west of Paulton church, I obtained a large *Nautilus* from limestones yielding *Spiriferina Walcotti*, *Pleuromya*, *Ostrea irregularis*, *Gryphæa arcuata*, *Lima gigantea*, and containing quartz pebbles.

The following section at Camerton was noted by Moore:—

| | | Ft. | In. |
|---|---|---|---|
| Middle Lias? | Irregular beds of marlstone | 2 | 0 |
| Lower Lias. | Nodular bed with *Ammonites raricostatus* | 0 | 3 |
| | Brownish clay | 2 | 0 |
| | Blue limestone with Fish-scales, *Aptychus*, and *Ammonites semicostatus* | 0 | 6 |
| | Foraminifera zone. Blue clay | 8 | 0 |
| | Spirifer Bank, indurated marl, with many specimens of *Spiriferina Walcotti* | 0 | 6 |
| | Limestones and clays (Lima series) | 4 | 10 |
| Rhætic Beds. | White Lias | 8 | 0 |

* See also section by Bristow, of a quarry N.W. of Welton. Geol. E. Somerset, &c., p. 97.

† Proc. Bristol Nat. Soc., ser. 2, vol. i. p. 179.

It was from this neighbourhood that a specimen of the *Spiriferina* was first figured by John Walcott.* Moore notes the occurrence of *Ammonites Bucklandi, A. Conybearei, A. angulatus, A. Turneri,* &c. The old pit is situated about ¼ mile N.N.E. of the church, and having long been disused when I visited it in 1885, in company with Mr. Martin F. Woodward, we had great difficulty in finding the Spirifer bank. In the lowest beds of hard grey shelly limestone, *Belemnites* and *Rhynchonella variabilis* were met with; and above, there were 5 or 6 feet of clay and sandy shales (with lumps of Carboniferous Limestone and occasional quartz pebbles), in the lower part of which *S. Walcotti* and *Gryphæa arcuata* were found. *Pholadomya ambigua* and *Ammonites bisulcatus* also occurred.

A somewhat similar section to that at Camerton, was exposed at Medyeat near Timsbury; there the Foraminifera zone (stiff blue clay, 7 ft. 6 in. thick), was exposed above the Spirifer-bed, the former being grouped by Prof. Tate in the zone of *A. oxynotus.* This classification must be regarded as approximate, for at Camerton Moore found *A. semicostatus* in the bed above the Foraminifera Zone.† (See p. 131.)

The following section in a quarry below Timsbury was noted by Tawney‡:—

| | | Ft. | Ins. |
|---|---|---|---|
| Zone of *A. obtusus,* &c. | Brownish-grey clay, &c. | 1 | 6 |
| | Greenish-grey limestone. *Ammonites obtusus, A. planicosta, Avicula inæquivalvis.* Fish-scales | 0 | 5 |
| Zones of *A. Bucklandi,* and *A. planorbis.* | Laminated brown clay | 2 | 6 |
| | Stiff blue clay, sandy at base, and with phosphatic concretions. *Ammonites sauzeanus, Nautilus, Belemnites penicillatus, Gryphæa arcuata, Pecten calvus, Spiriferina Walcotti, Terebratula punctata,* and lignite | 0 | 6 |
| | Thick grey limestone. *Ammonites sauzeanus, A. rotiformis, Gryphæa arcuata, Lima succincta, L. Hermanni, Rhynchonella variabilis, S. Walcotti,* and var. *Münsteri, S. rostrata, Terebratula punctata, Waldheimia cornuta* | 2 | 6 |
| | Brown clay. *G. arcuata, Lima Hermanni* | 0 | 1 |
| | Pale grey limestones and shales, with *Lima succincta, L. gigantea, L. Hermanni, Pinna, Unicardium cardioides, Pleuromya* | 4 | 8 |
| | Grey limestones, with partings of clay | 1 | 8 |
| Rhætic Beds | White Lias | 4 | 0 |

Tawney observed that he had not obtained *Ammonites angulatus* anywhere in the district. Prof. Tate, however, grouped the lower beds of Lias at Medyeat with that zone, and Moore has recorded the species from Camerton.

* Description and Figures of Petrifactions found in the Quarries, Gravel Pits, &c. near Bath. 8vo. London, 1779.

† See Moore, Proc. Somerset Arch. and Nat. Hist. Soc., vol. xiii., p. 154, and Quart. Journ. Geol. Soc., vol. xxiii. p. 471; Tawney, Proc. Bristol Nat. Soc., ser. 2, vol. i. p. 185; Tate, Quart. Journ. Geol. Soc., vol. xxxi. pp. 496, 497, and 501.

‡ Proc. Bristol Nat. Soc., ser. 2, vol. i. p. 182.

*Vale of Wrington.*

The Lower Lias limestones are exposed here and there at Chewton Mendip, Stone Easton, near Hinton Blewet, Burledge Hill, and near Stowey and Clutton*; but in this area the beds have not yielded the same number of organic remains that have been noticed further east. The quarries are not deep, seldom exposing more than 8 or 10 feet of limestones.

Westwards, the Lower Lias extends on to the Carboniferous Limestone of Broadfield Down, overlapping the Rhætic Beds in places. As remarked by De la Beche, in places the Lias becomes conglomeratic and partakes of the nature of the Sutton Stone of Glamorganshire.† The beds here were re-surveyed by Mr. Ussher. Moore noted the section as follows:—

| | Ft. | Ins. |
|---|---|---|
| Stone beds - - - - - - - | 10 | 4 |
| Ragstone and rubbly beds - - - - | 7 | 8 |
| Conglomerates. | | |
| | 18 | 0 |

He observed that "the abundance of *Modiola minima* and other remains shows clearly that this deposit belongs to the White Lias; but its texture is so precisely like the Sutton stone that it might readily be mistaken for that rock. Like the Sutton stone it is very durable, and may be raised in blocks of many tons weight. At the base of the quarry there are thick conglomerates with *Ostrea intusstriata*, the thicknesses of which are unknown, and in which galena is found, as at Sutton. A *Thecosmilia* in casts is rather plentiful at this place."‡

During a visit to the district in 1888 in company with Mr. C. Reid, we saw a freestone quarry at Downside. It showed from 18 to 20 feet of massive-bedded sparry lime-rock, evidently of detrital origin, and reminding me of the Doulting stone (Inferior Oolite). In both cases the rock may have been derived from the Carboniferous Limestone. The Downside rock may be described as a bastard freestone. The joints are smooth, and some beds are very shelly. Gasteropods, *Modiola*, *Cardinia*, and *Ostrea* were observed, but all poorly preserved. The weathering of the rock is cavernous, and on top there was about 1 foot of brown soil. The rock is somewhat porous in texture, but troughs, cornices, and building-stones are obtained from it. There can be little doubt that the beds are of the age of the Sutton Stone.

*Bath and Keynsham.*

The limestones, which represent so much of the Lower Lias around Radstock, become more restricted to the lower zones as we approach Bath and Keynsham. In the valleys east of Bath we have few sections of the strata, but the Blue Lias series is

* A section of the Lower Lias at Clutton is given by Messrs. Bristow and Etheridge in Vertical Sections, Sheet 46, No. 16.

† De la Beche, Mem. Geol. Survey, vol. i. p. 276. See also Tawney, Quart. Journ. Geol. Soc., vol. xxii. p. 79.

‡ Quart. Journ. Geol. Soc., vol. xxiii. p. 504.

well exposed at Weston, Twerton (Twiverton), Saltford and Keynsham.

The lowest beds are seen in the cutting of the Midland Railway west of Weston Station, where we find hard blue and grey limestones with shaly partings, containing *Ostrea liassica,* and resting on the White Lias. At the adjoining lime-works, nearer the railway-station, and on the south side of the railway, we find higher beds belonging to the zones of *A. angulatus,* and *A. Bucklandi.* The beds comprise hard blue and brown limestones and blue sandy shales, with *A. Bucklandi, Gryphæa arcuata, Lima gigantea* (small forms), *L. Hermanni, Ostrea liassica, O. irregularis,* and *Pecten lunularis.* At these lime-works the Blue Lias is burnt into brown lime, for building-purposes; and Carboniferous Limestone is burnt into white lime, for agricultural purposes.

Other quarries are situated to the north of the railway, and show the upper part of the stone-beds with 3 feet of brown and grey clay on top; and from these Moore obtained many fossils.* He has recorded, in addition to the species before mentioned, *Ammonites angulatus, A. Conybearei,* and *A. Turneri, Nautilus lineatus, N. intermedius, Pleurotomaria anglica* (and a number of other Gasteropoda), *Cardinia Listeri, Pholadomya ambigua, Plicatula intusstriata, Unicardium cardioides, Pecten Pollux, P. sublævis, Avicula inæquivalvis, Spiriferina Walcotti, Rhynchonella calcicosta,* together with some remains of Saurians, Fishes, &c. I have obtained also *Rhynchonella plicatissima, Terebratula punctata,* and *Pholadomya glabra.*

The full thickness of the Blue Lias series at Weston appears to be 56 feet.†

On the opposite side of the valley at Pennyquick near Twerton, the Blue Lias beds have been largely worked for road-stone and for lime-burning. At one quarry the beds are shown to a depth of 16 feet, and consist of blue and grey limestones, some irregular and nodular, with partings of clay and shale. The beds belong to the zone of *Ammonites Bucklandi,* and yield that fossil together with *Gryphæa arcuata, Pecten lunularis, Pholadomya glabra, Rhynchonella calcicosta, Pentacrinus basaltiformis,* &c. Morris records *Nautilus lineatus, Lima gigantea,* and *Pleurotomaria anglica.*‡

A fine section showing about 50 feet of the Blue Lias series down to the White Lias, was exposed in a cutting of the Great Western Railway west of Saltford, and has been recorded by Messrs. Bristow and Etheridge.§

North of Keynsham Station there is a quarry showing limestones with *Ammonites angulatus, A. rotiformis, A. semicostatus? Gryphæa arcuata* (abundant), *Pleuromya costata, Cardinia, Ostrea irregularis,* and *Rhynchonella plicatissima* (abundant).

* Moore, Quart. Journ. Geol. Soc., vol. xxiii. p. 497; see also Proc. Cotteswold Club, vol. iv. p. 84.

† Lonsdale, Trans. Geol. Soc., ser. 2, vol. iii. p. 243.

‡ Geol. Mag., 1868, p. 234.

§ Vertical Sections (Geol. Survey), Sheet 46, No. 9; see also sections by W. Sanders, Quart. Journ. Geol. Soc., vol. xvi. p. 399, Wright, Lias Ammonites, p. 36, and Phillips, Geol. Oxford, p. 113.

South-easth of Keynsham, the Lower Lias has been extensively quarried for building-stone and lime-burning. The stone-beds have been exposed to a depth of about 20 feet; the upper part shows thin and even-bedded limestones and clays, the lower beds comprise limestones divided by thin shaly and sandy partings. The fossils here found were *Nautilus*, *Ammonites Bucklandi*, *Gryphæa arcuata*, *Lima gigantea* (small), and *Ostrea liassica*; the beds representing the zones of *A. Bucklandi* (lower part) and *A. planorbis*. Many Gasteropods and other fossils have been obtained by Moore. In the uppermost portion of the zone of *A. Bucklandi*, he noticed a thin band of indurated marl with Plant-remains and Fishes (*Hybodus*, *Acrodus*, *Lepidotus*, &c.) and *Avicula inæquivalvis*.*

The enormous Ammonites found in the limestones, of the Lower Lias at Keynsham, have given rise to the same romantic legends respecting the miraculous powers of St. Keyna, as have prevailed concerning St. Hilda at Whitby.† *Ammonites Bucklandi* 1 ft. 9 in. in diameter has been obtained, and near Saltford *A. Conybearei* having a diameter of 1 ft. 6 in. Large examples of *A. Bucklandi* are occasionally found without the inner whorls; and such was the case with the specimen originally obtained by Buckland, who, thrusting his head through it, rode home, dubbed by his friends the *Ammon Knight*.‡ *Extracrinus briareus* has also been recorded from Keynsham.

At Keynsham Hams, borings of Mollusca? and marks of erosion are stated by Bristow to occur in the top of the Sun bed.§

The general characters of the Lias at Bath may be inferred from the following section, furnished by a fruitless trial for coal, which was made at Batheaston, and abandoned in 1812:—||

| | Ft. | In. | | Ft. | In. |
|---|---|---|---|---|---|
| Upper Lias? and Middle Lias | 104 | 4 | Yellow clay | 8 | 0 |
| | | | Blue marl with bands of stone | 54 | 10 |
| | | | Blue rock | 12 | 0 |
| | | | Marl | 1 | 0 |
| | | | Stone | 1 | 6 |
| | | | Blue marl | 24 | 0 |
| | | | Rock | 3 | 0 |
| Lower Lias | 142 | 8 | Blue marl with bands of stone | 65 | 9 |
| | | | Marl and stone | 41 | 6 |
| | | | Hard rock and blue stone | 35 | 5 |
| Rhætic Beds | 36 | 3 | Stone [Sun bed?] | 2 | 0 |
| | | | White lias rock | 10 | 0 |
| | | | Blue marl | 6 | 0 |
| | | | Stone, clay, and rough blue marl | 6 | 3 |
| | | | Black marl | 10 | 0 |
| | | | Light blue marl | 2 | 0 |
| Red Marls | 30 | 0 | Red ground | 30 | 0 |
| Dolomitic Conglomerate | 24 | 0 | Mill-stone | 24 | 0 |
| | | | | 337 | 3 |

* Moore, Quart. Journ. Geol. Soc., vol. xxiii. p. 502.

† Buckland and Conybeare, Trans. Geol. Soc., ser. 2, vol. i. p. 302.

‡ Sowerby, Mineral Conchology, vol. ii. p. 69.

§ Vertical Sections, Sheet 46, No. 12.

|| From document presented to the Geological Society by Mr. Meade, Hon Mem., Feb. 2, 1810. This record differs slightly from that given by Conybeare and Phillips, Outlines of Geol. England and Wales, p. 262. See also Moore, Quart. Journ. Geol. Soc., vol. xxiii. p. 458.

The boring extended to a depth of 68 feet beneath this. The grouping of the divisions of the Lias is given with considerable hesitation; it is doubtful if Upper Lias be present.

We have, however, evidence to show that the thickness of the Blue Lias limestones, which in this neighbourhood include the zones of *Ammonites planorbis*, *A. angulatus*, and *A. Bucklandi*, attain a thickness of 76 feet. This thickness becomes reduced at Twerton to 66 feet,* as proved in a boring at the coal-pit; and it is much about the same thickness at Bath.†

Of the clayey beds of the Lower Lias, near Bath, we have few sections and but little palæontological information. A brickyard south of the Great Western Railway and east of Twerton station, showed about 15 feet of brown and blue mottled marly clay with ochreous nodules, and bands of fissile sandy and calcareous stone; and these beds overlie stiff blue clay with Belemnites.

At the Bath waterworks, situated in the valley east of Swainswick, Moore obtained *Hippopodium ponderosum*, a fossil exceedingly rare in the district to the south, but abundant at certain horizons near Cheltenham, and further north.

Lonsdale estimated the total thickness of the Blue clay and marl (above the Blue Lias limestones) at Bath at 200 feet;‡ and this argillaceous series includes the beds up to the Midford Sands at the base of the Inferior Oolite.

### *Chew Magna and Bristol to Purton Passage.*

The Lower Lias forms a broad platform north of Chew Magna on which lies the Inferior Oolite of Dundry. The higher beds of the Lias in this area are so rarely exposed that but little is known about them. The Lower Lias may be about 350 feet thick §

*Ammonites Turneri* has been obtained from the Lower Lias at the Reservoir at Barrow Gurney. Northwards at Castle Farm, on the Bedminster Road, the limestones have been quarried in places. We find brown clays and limestones, resting on dark blue clays, with bands of yellow (iron-stained) limestone, near the top of which Mr. E. Wilson has obtained some Gasteropoda. The fossils include *Ammonites angulatus, Nautilus, Pleurotomaria, Lima gigantea, L. Hermanni*, &c. showing that here the zone of *A. angulatus* is represented.

Bristow noted a quarry west of the high road at Upper Knowle, south-east of Bristol, where the lower beds with *Lima gigantea*, and *Ostrea liassica*, were shown‖; and Moore recorded

* De Rance, Rep. Brit. Assoc. for 1875, p. 132.

† See section by Moore, at Kingsmead Street, Bath. In the account given, too great a thickness is assigned to the White Lias. Quart. Journ. Geol. Soc., vol. xxiii. p. 496.

‡ Trans. Geol. Soc., ser. 2, vol. iii. p. 243.

§ See section by W. W. Stoddart, Wright, Lias Ammonites (Palæont. Soc.), p. 148.

‖ Vertical Sections (Geol. Survey), Sheet 46, No. 4.

a section of the lowest beds of the Lower Lias at Bedminster Down.* His section is as follows:—

| | | Ft. | Ins. |
|---|---|---|---|
| Zone of *Am. planorbis.* | Limestones and clays - - - - | 6 | 2 |
| | Laminated stone with *Ammonites planorbis* and Insects - - - - - | 0 | 7 |
| | Limestones and marls, with Ostracoda - | 4 | 5 |
| | Limestone with *Lima gigantea*, *L. tuberculata*, *Ostrea multicostata* - - - - | 0 | 7 |
| | Limestones and marls with *Ostrea liassica*; Insect and Crustacea bed at base - - | 4 | 0 |
| Rhætic Beds - | White Lias. | | |

*Lima gigantea*, as remarked by Prof. Tate, here seems more prevalent in the lower stages of the Lias than it is further south,† but as a rule we find only small specimens.

We have no evidence of any mass of limestones representing the zone of *Ammonites Bucklandi* far to the west of Keynsham. Passing to the north of the Avon we find outlying masses of Lower Lias and Rhætic Beds; and the Lower Lias overlaps on to the Carboniferous Limestone west of Horfield and Alveston, showing that promontories or islands of the older rocks stood out in the Liassic seas. The Bristol Coal-field itself was no doubt covered at one time by the higher beds of the Lower Lias.

W. W. Stoddart has described the beds at Ashley Down, Montpelier, and Cotham. At the first-named locality, the zone of *Ammonites Turneri*, consisting of shales 2 feet 3 inches in thickness, is exposed. The zone of *A. Bucklandi*, which is just reached at the Ashley Down Quarry, is passed through at the Montpelier Quarry. This zone consists of limestones and shales, about 22 feet in thickness. The zone of *A. planorbis* beneath, is worked at the Montpelier Quarry and at Cotham. It consists of shaly beds and limestones; and at Cotham the White Lias is reached.‡ *Avicula cygnipes* is found at Montpelier; and this fossil seems most abundant in the lowest beds of the Lias in this area, at Aust, &c. *Ammonites Johnstoni* occurs at Cotham.

The basement-beds of the Lower Lias have been opened up at Horfield, near Stoke Gifford and Alveston. From Horfield, Bristow obtained *A. planorbis*, *Ostrea liassica*, spines of *Cidaris*, &c.; also, in higher beds, remains of *Gyrolepis*, *Pholidophorus*, and *Ammonites laqueolus* (*tortilis*).§ *A. angulatus* has also been found at Horfield.

In some portions of the Bristol area, the Lower Lias appears to rest directly on a bed resembling the Landscape or Cotham Marble, and Bristow then took this rock as the upper limit of the Rhætic formation. At Cotham about 2 feet of the White Lias

* Quart. Journ. Geol. Soc., vol. xxiii. p. 500; see also E. Wilson, *Ibid.*, vol. xlvii. p. 545.

† *Ibid.*, vol. xxxi. p. 496.

‡ Quart. Journ. Geol. Soc., vol. xxiv. p. 199. See also C. O. G. Napier, *Ibid.*, p. 204.

§ A section at Horfield, showing about 28 feet of Lower Lias, is given by Bristow in Vertical Sections, Sheet 46, No. 2. An analysis of Lias limestone from Stapleton, near Bristol, was published by A. Voelcker, Journ. Bath and W. of Eng. Soc., ser. 2. vol. vi. p. 225.

may be seen above the Marble; but elsewhere in the area, distinctive beds of White Lias are not always to be found, and it is possible there is some overlap of the White Lias.* Near Bath, the Landscape Marble occurs at the base of the White Lias; but beds of similar texture occur at other horizons in that division.

At Aust Cliff we find thin beds of the Lower Lias, mostly inaccessible, capping the Rhætic Beds.† It is remarkable that here the uppermost band of the Rhætic Beds, is a stone that resembles the Cotham Marble in texture, and judging by the section at Garden Cliff, it is on the horizon of the *Monotis*-bed of that locality. It rests on bluish-grey marls and marly limestones, 8 ft. 6 in. thick, that represent the White Lias, as do similar beds at Penarth and other places. The *Estheria*-bed of Garden Cliff, is an irregular limestone that occurs near the base of the marly beds of White Lias; and it exhibits arborescent markings.

The Lower Lias consists of even-bedded limestones and clays, with *Lima gigantea*, and at the base thin shaly marl with *Ostrea liassica*, *Pleuromya*, and *Avicula cygnipes*. These beds belong to the zone of *Ammonites planorbis*, and Dr. Wright thought the zone of *A. angulatus* was also represented at this locality.

West of Londonderry, to the north of Keynsham, we find about 25 feet of limestones and clays with *Ammonites Bucklandi*, overlying thinner beds of limestone and brown clay. Among the fossils found were *A. angulatus*, *A. Johnstoni*, *A. semicostatus?* *Cardinia*, *Gryphæa arcuata*, *Lima gigantea* (large and small), *Pholadomya glabra*, *Pleuromya costata*, *Unicardium cardioides*, *Rhynchonella*, and *Waldheimia perforata*. The species were identified by Messrs. Sharman and Newton.

In the cutting of the Midland Railway near Willsbridge, the Lias and Rhætic Beds are faulted against the Pennant Grit. The section shows 25 beds of Lower Lias limestone, with intervening layers of marl, containing *Lima gigantea*, *Nautilus*, *Ammonites Bucklandi*, *A. planorbis*, &c.‡ A curious nodule termed a "Peg-top" by the workmen, was obtained by Major Bonus, R.E., from the Lower Lias in this railway-cutting, and is now in the Museum at Jermyn Street.

Northwards, the Lower Lias forms a broad vale from Doynton by Pucklechurch to Hawkesbury and Wotton-under-Edge. This is essentially a clayey tract with few sections, probably because the Lias limestones are feebly developed, as is the case in the vale of Gloucester further north.

The Lower Lias and the Rhætic Beds here rest in places directly on the Carboniferous Limestone, which comes to the surface at the "Grammar Rock," north-west of Lansdown, at the "Wick Rocks," and again to the west of Codrington Court.

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* H. B. Woodward, Quart. Journ. Geol. Soc., vol. xlvii. p. 549; Geol. Mag., 1892, p. 333.

† See section by Bristow and Etheridge, Vertical Sections, Sheet 46, No. 6.

‡ See Moore, Quart. Journ. Geol. Soc., vol. xxiii. p. 498.

Clays with bands of cherty limestone were noted by Weaver at Inglestone (Ingatestone) Common between Wickwar and Hawkesbury Upton; and there *Ammonites*, *Gryphæa*, *Lima*, and *Ostrea* were obtained.*

At Tites Point, Purton (or Pyrton) Passage, there were formerly some good exposures of the Lower Lias limestones alternating with clays and marls. The beds were rich in fossils and attracted attention at a very early date, for they are mentioned by J. Woodward in 1706.† The fossil-beds were exposed in ledges at ebb-tide along the Severn shore; and the beds abutted against the Silurian rocks, for Weaver‡ mentions (1819) that the actual contact of the older rocks with the Lias was observable "at low water, at the landing place immediately under the Passage-house." Twenty years later, the Lias was no longer visible, for as pointed out by Murchison,§ the process of encouraging the mud of the Severn to accumulate upon lines of pile and osier, effectually buried the Liassic ledges beneath a slimy sediment.

The limestone appears to have occurred in impersistent, and more or less nodular masses, and among the fossils recorded are *Ammonites Bucklandi*, *Nautilus*, *Belemnites*, *Pleurotomaria anglica*, *Gryphæa*, *Lima*, *Pentacrinus*, &c., representing in the main the zone of *Am. Bucklandi*. Probably beds both at lower and higher horizons were exposed, for *Hippopodium ponderosum* has been mentioned; a form that usually occurs at a higher stage in the neighbourhood of Cheltenham.

The Rev. P. B. Brodie, who has given some account of the beds,‖ obtained among other fossils a specimen of *Involutina liassica*, a Foraminifer, in form like a Nummulite.¶

A little way inland there was a section exposing bluish-grey shales and nodular grey limestones from which I obtained *Ammonites angulatus*, *A. Bucklandi*, *Gryphæa arcuata*, and *Lima gigantea*.

*Fretherne, Westbury-on-Severn, and Stroud.*

For some distance between Purton Passage and Tewkesbury, the Severn takes a winding course that roughly follows the strike of the Lower Lias.

At Hock Crib, Fretherne, the Lower Lias is exposed in the low cliffs bordering the river. The beds are a little disturbed, as they undulate and are slightly displaced at one point. The section was described in 1853 by the Rev. P. B. Brodie,** and in more detail, in 1883, by Mr. W. C. Lucy.††

The beds comprise about 40 feet of clays or shales with about 10 bands of limestone; the latter forming ledges and platforms on

* Trans. Geol. Soc., ser. 2, vol. i. p. 350.

† Nat. Hist., Foss, England, vol. i. part 2, p. 80; vol. ii. pp. 8, 25.

‡ Trans. Geol. Soc., ser. 2, vol. i. p. 330.

§ Silurian System, p. 450.

‖ Proc. Cotteswold Club, vol. i. p. 243, and Geologist, vol. i. p. 72; see also J. Jones, Proc. Cotteswold Club, vol. iii. p. 134.

¶ T. R. Jones, Geol. Mag. 1864, p. 193.

** Proc. Cotteswold Club, vol. i. p. 241.

†† *Ibid.*, vol. viii. p. 131.

the foreshore, and protruding some way in places beneath the Alluvial mud of the Severn. It was observed by George Cumberland in 1822, that "We can walk at low-water on the blue lias of Fretherne, to the extent of half a mile, as on an extensive level floor, and there see enormous ammonites under our feet, some exceeding four feet in diameter."* The beds are no longer exposed to this extent, but, as at Llantwit in Glamorganshire, we can observe the clusters of fossils here and there on the Liassic pavements: *Pecten textorius, Avicula cygnipes, Lima gigantea*, and *Pentacrinus* occurring abundantly in portions of the rock, which elsewhere appear unfossiliferous.

The most noteworthy fossils of Fretherne are the *Gryphæas* (*G. arcuata*). They occur in profusion here and there in the shales and limestones, and I have nowhere seen finer examples. They may be found at all horizons in the cliff-section, but are most abundant in the lower beds, and especially in a band of shale, above which I obtained a small example of *Ammonites angulatus*. The beds belong to the zones of *A. angulatus* and *A. Bucklandi*, and perhaps include higher stages, for Mr. Lucy records *A. semicostatus*, and I obtained a specimen of *A. obtusus*. Judging by these fossils the thickness of the zone of *A. Bucklandi* is not above 20 feet. It is noteworthy, however, that *A. Bucklandi* and *A. semicostatus* occur together about mid-way up in the beds exposed; and Mr. Lucy notes *A. Conybearei* together with *A. Johnstoni, Avicula cygnipes*, etc., in a band near the base of the cliffs. Many other fossils have been recorded by Messrs. Brodie and Lucy, including the *Involutina*, also *Discina babeana* (*Orbicula Townshendi*), spines of *Cidaris*, vertebræ of *Ichthyosaurus*, &c.†

In an account of the Geology of Awre, published in 1830, the Rev. C. P. Wilton,‡ at that time curate of the parish, records many fossils from the Blue Lias. These include *Ammonites Bucklandi* (3 feet in diameter), *Lima gigantea, Avicula, Gryphæa arcuata*, Pentacrinites, &c., together with bones of Saurians; a group that indicates the zone of *Ammonites Bucklandi.*

The basement-beds of the Lower Lias (zone of *Ammonites planorbis*) are shown in Garden Cliff, to the south of Westbury-on-Severn; and according to E. Witchell the beds have been opened up at Elmore.§ At Garden Cliff the section of the beds is as follows‖:—

| | | Ft. | In. |
|---|---|---|---|
| Lower Lias | Tumbled beds of grey earthy limestone and clay, with *Ostrea liassica*, &c. | | |
| | Compact blue and grey limestone, with *O. liassica, Modiola minima*, &c. | 0 | 2 |
| | Brown marly shales | 1 8 to 2 | 0 |
| Rhætic Beds | Smooth slaty limestone (Monotis Bed) with *Monotis decussata* | 0 | 6 |

* Trans. Geol. Soc. ser. 2, vol. i. p. 370.

† The list given in Hull's Geol. Cheltenham, p. 16, is wrongly stated to be from the "Bone Bed," and the occurrence of some of the species mentioned is exceedingly doubtful.

‡ Quart. Journ. Sc. Lit. and Arts, N.S., 1830, p. 69. A shell (*Leda*) discovered by R. Ryder of Awre is here named *Ryderia*.

§ Geology of Stroud, pp. 8, 9. See also Proc. Cotteswold Club, vol. iv. p. 56.

‖ See also Bristow and Etheridge, Vertical Sections (Geol. Survey), Sheet 46, No. 7.

The Brown marly shales above the *Monotis*-bed are probably equivalent to similar shales that occur at the junction of the Lower Lias and Rhætic Beds at Penarth. (See p. 119.)

In the vale that extends eastward by Frocester and Stonehouse, we find for the most part a clay-flat, but according to E. Witchell, the zone of *Am. Bucklandi* is represented near Eastington and Whitminster by clays, with bands of limestone that form low ridges.*

Dark shales with bands of limestone are exposed in the banks of the Ship Canal north of Hardwicke, and again between Rea and Syms Bridges, north of Quedgley, where the beds are bent into a gentle synclinal. At Hardwicke, according to Dr. Wright, we meet with the zone of *A. Turneri* (or *A. semicostatus*).

Higher beds of clay have been opened up in some of the brick-yards between Stonehouse and Stroud, and exposed in the railway-cuttings. *Ammonites oxynotus* has been found at Stonehouse, and pyritic ammonites, including *A. densinodus* and *A. subplanicosta*, belonging to the zone of *A. armatus*, have been found at Standish. Near the Gas-works at Stroud, clays representing the zones of *A. Ibex* and *A. Henleyi* have been noted by E. Witchell; and Mr. Lucy informed me that the zone of *A. Henleyi* had been proved at Brookthrop (Brookthorpe).

*Gloucester and Cheltenham.*

In the neighbourhood of Gloucester, the lowest beds of the Lias have been well exposed in the railway-cutting at Lassington. The section is as follows† :—

| | | Ft. | In. |
|---|---|---|---|
| Lower Lias (Zone of *Am. planorbis*). | Clays and shales, with three bands of nodular blue-hearted limestone: *Ammonites Johnstoni* - - - - - about | 30 | 0 |
| | Band of bluish-earthy limestone with *A. planorbis* - - - - - | 0 | 4 |
| | Marly shales and limestones: *Pleuromya crowcombeia* - - - about | 7 | 0 |
| | Three bands of blue argillaceous limestone and shale, with *Ostrea liassica* and *Modiola minima* in bottom bed - - - - | 1 | 4 |
| | Papery shales - - - - | 3 | 0 |
| | Hard compact grey limestone, with blue shelly layer and conglomeratic fragments. *Monotis decussata*. Fish-remains. *Otozamites gracilis* - - - - | 0 | 4 |
| Rhætic Beds - | Dark shaly marls, etc. (faulted against the Keuper Marls). | | |

The basement-bed, here grouped with the Lower Lias, has in many respects a Rhætic aspect, the matrix being like Cotham Marble in texture. It indicates however some change in conditions, like the bottom bed of Lias noticed at Stormy Down near Bridgend, and the "Guinea Bed" of Warwickshire. It appears

* Geol. Stroud, p. 16.
† See also W. C. Lucy, Proc. Cotteswold Club, vol. viii. p. 225.

to be a remanié bed, and therefore to be grouped more appropriately with the Lower Lias than the Rhætic Beds, suggesting slight unconformable overlap of the Lias. (*See* p. 151.)

Nearer Gloucester, a cutting in the same railway, not far from the main road, showed higher beds, comprising clays, with here and there a band of limestone, yielding *Gryphæa arcuata*, *Rhynchonella calcicosta*, and bones of *Ichthyosaurus*.

In the Ship Canal east of Hempstead, blue and grey marly shales are exposed, while at the brickyard and adjoining gasworks on the south, blue micaceous clay with *Gryphæa arcuata* has been exposed to a depth of 25 feet. In the old brickyard near Llanthony Priory, Gloucester, *G. arcuata* and varieties, were obtained by John Jones,* together with *Ammonites* suggesting the zone of *A. obtusus*. Mr. Lucy records the finding of *A. stellaris* by the canal at Hempstead wharf, and also at Over, so that Gloucester appears to be situated on the zone of *A. obtusus*. Moreover the evidence goes so prove that the series, upwards from the zone of *A. planorbis*, contains no important mass of limestones.

A boring for water, made in 1883, at Westgate Street, Gloucester, proved the following beds, which were recorded by Mr. Lucy† :—

| | | Thickness. | | Depth. | |
|---|---|---|---|---|---|
| | | Ft. | In. | Ft. | In. |
| | Made ground and gravel | 16 | 0 | 16 | 0 |
| | Hard and soft blue and grey clay | 154 | 0 | 170 | 0 |
| | Very hard stone | 5 | 0 | 175 | 0 |
| | Clay | 2 | 0 | 177 | 0 |
| | Stone | 1 | 6 | 178 | 6 |
| | Clay and shale, with shells and pyrites | 48 | 6 | 227 | 0 |
| | Stone with *Ammonites*, Pecten, and *Gryphæa arcuata* | 0 | 3 | 227 | 3 |
| | Blue clay with *Gryphæa*, &c. | 36 | 9 | 264 | 0 |
| | Shaly clay with *Astarte*, *Cerithium*, *Avicula inæquivalvis*, *Gryphæa* | 24 | 0 | 288 | 0 |
| Lower Lias | Clay with *Ammonites semicostatus* | 6 | 0 | 294 | 0 |
| | Grey clay | 12 | 0 | 306 | 0 |
| | Grey stone | 2 | 2 | 308 | 2 |
| | Hard clay | 3 | 10 | 312 | 0 |
| | Clay with *Ammonites*, *Avicula*, *Gryphæa*, and *Lima* | 4 | 6 | 316 | 6 |
| | Clay with *Am. semicostatus*, *Gryphæa* | 12 | 6 | 329 | 0 |
| | Clay | 8 | 0 | 337 | 0 |
| | Clay with *Cerithium*, *Pleuromya* | 3 | 0 | 340 | 0 |
| | Hard clay with *Tornatella* or *Cylindrites* | 10 | 6 | 350 | 6 |

At Badgworth we find clays with nodular limestones, yielding *Ammonites bisulcatus*, *Gryphæa*, &c.; and Dr. Wright notes the occurrence of beds representing the zone of *A. Turneri*.‡ Occa-

* Proc. Cotteswold Club, vol. iii., Supplement 4to.
† *Ibid.*, vol. viii. p. 213.
‡ Lias Ammonites (Pal. Soc.), p. 47.

sional bands of rubbly limestone occur in the clays at Upton St. Leonards.*

At the Cheltenham gas-works, north-west of the Great Western railway-station, a deep excavation was made in 1887, in blue marly clay. Here Mr. E. Wethered obtained many specimens of *Gryphæa obliquata*, *G. cymbium*, and varieties not to be distinguished from *G. arcuata*, also small specimens of *Hippopodium ponderosum*, *Ammonites quibalianus*, and *A. Greenoughi*.

Dr. Wright remarked that *A. armatus* and *A. oxynotus* occur together at Cheltenham. We find a somewhat similar assemblage at Hill Moreton, near Rugby. A list of fossils, indicating beds belonging to the zones of *A. oxynotus* to *A. Henleyi*, has been given from the blue calcareous clay in the railway-cutting of Denbury Hill, Cheltenham†; but the list requires revision.

At Hucklecote brickyard south-west of Brockworth, we find about 10 feet of bluish-grey and brown marly clay with small nodules of earthy limestone. From these beds I obtained *Ammonites striatus*, *A. scipionianus*, *A. Valdani*, *Belemnites compressus*, *B. longissimus*, *Chemnitzia*, *Inoceramus*, &c. The species were identified by Messrs. Sharman and Newton.

Dr. Wright notes that, in an excavation made at Marle Hill, north of Cheltenham, for brickearth, the following section was obtained‡:—

| | | Ft. | In. | Ft. | In. |
|---|---|---|---|---|---|
| Lower Lias | Gryphæa-bed, ferruginous clay with *G. obliquata* | 3 | 0 to | 4 | 0 |
| | Coral-band, clay with *Montlivaltia rugosa* | | | 0 | 1 |
| | Hippopodium-bed, dark clay with *Hippopodium ponderosum* and *Cardinia Listeri* | 8 | 0 to | 10 | |
| | Ammonite-bed, dark clay with pyritic fossils, *Ammonites subplanicosta*, *A. densinodus*, *A. raricostatus*, *A. nodotianus*, &c. | | | | |

At Cleeve, near Cheltenham, the same beds were formerly worked for brickearth; and Dr. Wright mentions that there the finest specimens of *Cardinia Listeri*, *Hippopodium ponderosum*, *Pleurotomaria anglica* and *Ammonites raricostatus* were obtained.

The Rev. T. W. Norwood (now of Wrenbury) informed me he had obtained *Ammonites Jamesoni* from excavations at the Old Royal Wells and New Ladies' College at Cheltenham. At the Hucklecote brickyard rolled specimens of this species, &c., occur in the gravel on top of the clay.

Again at Cranham Pottery about 12 or 15 feet of blue micaceous clay, containing a few ferruginous nodules, has been exposed. There I obtained specimens of *Ammonites striatus* and *A. Jamesoni*? Flower-pots, pans, drain-pipes, jugs, &c. are manufactured at this pottery, which dates back to the time of Queen Elizabeth, if not earlier.

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* Hull, Geol. Cheltenham (Mem. Geol. Survey, Sheet 44), p. 15.
† *Ibid.*, p. 17.
‡ Lias Ammonites, p. 55.

Beds on much the same horizon, together with higher strata, occur at Pilford, near Leckhampton, where the brickyard showed blue and brown loamy clays, with a band of ironstone nodules, yielding *Ammonites*, *Avicula inæquivalvis*, *Pecten æquivalvis*, *Pholadomya*, and *Pleuromya*. These beds rest on blue pyritic and micaceous sandy clays, with iridescent fossils. Prof. Tate records from this locality, *Ammonites armatus*, *A. Jamesoni*, *A. Valdani*, *A. Ibex*, *A. Henleyi*, *Belemnites clavatus*, *Inoceramus ventricosus*, *Waldheimia numismalis*, &c.*; the fauna resembling that from Aston Magna, and including the zones of *A. Jamesoni* and *A. Henleyi*.

From the brickyard east of Cheltenham, I obtained *Ammonites Jamesoni*, *A. Loscombei*, *A. striatus*, *A. Valdani*, *Belemnites*, and *Inoceramus ventricosus*; fossils that indicate portions of the same zones as occur at Pilford.

*Ammonites striatus* (near to *A. Henleyi*) has been found abundantly in pits near Charlton Kings, as mentioned by Murchison, who originally figured the species under the name of *A. cheltiensis*. It occurs also in the brickyard north-east of Shackels Pike, and near Hewlets.† In this neigbourhood rugose forms of *Hippopodium ponderosum* have been found, together with *A. Henleyi* or *A. striatus*.

Prof. Hull notes the occurrence of ferruginous concretionary nodules, so characteristic of the upper beds of the Lower Lias, in brickyards at Hewlets Hill and in the lane leading from Heartly Hill to Charlton Kings.‡

### *Tewkesbury to Pershore.*

The basement-beds of the Lower Lias have been exposed in quarries in the neighbourhood of Tewkesbury, where the limestones are more prominently developed than further south in the Vale of Gloucester.

Here we come into the region of the "Insect Limestones" of the Rev. P. B. Brodie,§ a term applied to certain bands of limestone that occur at or near the base of the Lower Lias or the top of the Rhætic Beds, on the borders of Gloucestershire, Worcestershire, and Warwickshire.

The characteristic beds, which are now best shown between Evesham and Wilmcote, are banded limestones that split up more or less readily along the planes of stratification, and frequently display remains of Insects (chiefly Coleoptera), and Crustacea belonging to the genus *Eryon*, &c. These beds clearly occur in the Lower Lias (zone of *Ammonites planorbis*), and usually above

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* Quart. Journ. Geol. Soc., vol. xxvi. p. 396.

† Murchison, Geology of Cheltenham, 1834, pp. 19, 20; Strickland, Trans. Geol. Soc., ser. 2, vol. vi. p. 552, and Memoirs, p. 139; Brodie and Buckman, Quart. Journ. Geol. Soc., vol. i. p. 220; Tate, *Ibid.*, vol. xxxi. p. 508.

‡ Geol. Cheltenham (Geol. Survey), p. 18.

§ Proc. Geol. Soc., vol. iv. 1842, p. 15; Fossil Insects, pp. 56, &c.; and Geologist, vol. i. p. 375.

one or more bands of limestone (*Ostrea*-beds) that yield many specimens of *Ostrea liassica.*

The term "Insect Limestone" has however been applied indiscriminately, to beds that have yielded remains of Insects, and some of the beds evidently belong to the Rhætic series.

Among the localities where these Insect Limestones have been noted by Mr. Brodie, and by W. R. Binfield, Strickland, and others, are Hasfield, Wainlode Cliff, Apperley (the Grey hill), Forthampton, and Strensham; but the quarries are now mostly abandoned.

As no good section of the beds at Strensham is now exposed, it will be best to record that given by Buckman, Strickland, and Brodie.* It was one of the quarries opened near the escarpment, about two miles from Defford Station, and 4 or 5 miles north of Tewkesbury:—

| | | Ft. | In. |
|---|---|---|---|
| Lower Lias | Soil and clay | 4 | 0 |
| | Chance Rub. White limestone | 0 | 4 |
| | Clay, with *Ammonites planorbis* | 2 | 0 |
| | Double Nurf. Two bands of limestone with clay-parting. Saurian remains | 0 | 6 |
| | Bluish clay | 3 | 0 |
| | King's Nurf. Rough argillaceous limestone with *Ostrea liassica* (Ostrea Bed) | 0 | 3 |
| | Black clay | 3 | 0 |
| | Queen's Nurf. Rough argillaceous limestone | 0 | 3 |
| | Blue clay | 0 | 3 |
| | Hard blue limestone with *Modiola minima* | 0 | 6 |
| | Paving Stone, 3 in. divided by clay 1 in. with *O. liassica* and *M. minima* | 0 | 4 |
| | Black shale, with Fish-scales, *Cidaris*, and bivalves | 0 | 6 |
| | Brick Bed. Square blocks of hard stone, used for walls | 0 | 5 |
| | Shale | 0 | 3 |
| Rhætic Beds | Bottom Bed. Insect Limestone, generally blue, and very hard fine-grained, fissile limestone | 0 | 6 |
| | Blue shale | 1 | 3 |
| | Soft light blue limestone, with casts of *Arca*, *Cardium*, &c. | 0 | 4 |
| | | 17 | 8 |

The term Bottom Bed is applied to the lowest bed of economic value.

When we compare this section with the beds of Wilmcote and other places north-east of Evesham, we cannot doubt that the Insect Limestones are on different horizons. Here at Strensham, and also at Coomb Hill and Wainlode, the Insect Limestone comes beneath the *Ostrea*-beds, and so far as can be judged from the succession of the strata, subject as they are to local modifi-

* Murchison, Geol. Cheltenham, new ed. by J. Buckman and H. E. Strickland, p. 49; Brodie, History of Fossil Insects, p. 70.

cations, the bands at these localities belong rather to the Rhætic Beds than to the Lower Lias. The *Monotis*-bed of Garden Cliff appears to be on the same stratigraphical horizon.

Under these circumstances it is not desirable to adopt the name "Strensham Series," which was proposed by Prof. Judd for the "Fish and Insect Limestones" that occur at the base of the Lower Lias.* Nor did he include in the series the overlying beds with *Ammonites planorbis* and *A. Johnstoni*, which form an essential part of the basement-beds of the Lower Lias at Strensham, Wilmcote, and other places. Were we, indeed, to employ the term "Strensham Series," we should include only a few bands of limestone, in some places of Lower Lias, in others of Rhætic age.

The section of the upper part of Wainlode Cliff, described by Strickland and the Rev. P. B. Brodie, is as follows† :—

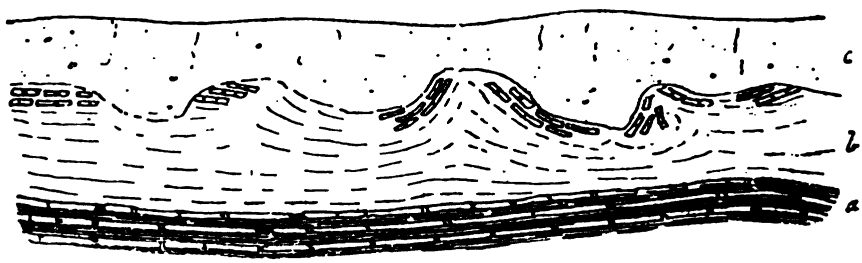
| | | Ft. | In. |
|---|---|---|---|
| Lower Lias | Top beds (concealed). | | |
| | Dark clay - - - - - - | 3 | 6 |
| | Blue limestone with *Ostrea liassica* and *Modiola minima* - - - - | 0 | 4 |
| | Yellow Shale - - - 0 ft. 6 in. to | 1 | 0 |
| Rhætic Beds | Insect Limestone. Grey and brown laminated limestone - - - - - | 0 | 5 |
| | Marly clay - - - - - - | 5 | 3 |

The westerly extension of the Lias is marked by the small outlier on the summit of Berrow Hill, two miles south-east of Keys-End Hill, the southern end of the Malvern range. Here only the basement-beds of the Lower Lias are found, above the Rhætic Beds, and they have been quarried for lime-burning.

Remains of *Ichthyosaurus* and *Plesiosaurus* have been obtained from the quarries at Woolridge east of Hartpury, on Brockridge Common, Hill Croome, east of Boughton, and on Defford Common. On this account the strata were called the "Saurian

Fig. 51.

East. *Section at Croome D'Abitot, near Pershore, Worcestershire.* West.




*c*. Drift. Reddish-brown sandy clay with pebbles of quartz, &c.
*b*. Grey marly clay, with thin bands of limestone (disturbed) } Lower Lias.
*a*. Limestones and shales. }
Depth of section, about 8 feet.

* Geol. Rutland, &c. (Mem. Geol. Survey, Sheet 64), p. 58.
† Strickland, Proc. Geol. Soc., vol. iv. p. 18; Murchison, Geol. Cheltenham, ed. 2, p. 48; Brodie, Fossil Insects, p. 57; Wright, Lias Ammonites, p. 18.

Beds" by J. Buckman and Strickland. Among other fossils are Fish-remains, *Dapedius orbis*, Crustaceans of the genus *Eryon*, and Plant-remains, such as *Otozamites*. Specimens of *Ammonites Johnstoni* are known to the quarrymen as "clock-faces," and this species is more common than *A. planorbis*. *Pleuromya crowcombeia* is also found in places. The best section that I saw, during my examination of this part of the country, was at a lime-kiln north of Croome D'Abitot. It was as follows (*see* Fig. 51):—

| | | Ft. | In. |
|---|---|---|---|
| Brown soil, and contorted rubble of limestone | | 5 | 0 |
| Lower Lias | Grey clay with thin bands of limestone | 5 | 0 |
| | Blue limestone with *Ostrea liassica* and *Modiola* | 0 | 4 |
| | Clay with band of bluish-grey limestone | 1 | 0 |
| Rhætic Beds | Hard blue and rather compact limestone | 0 | 7 |
| | Shaly clay | 0 | 8 |
| | Pale grey earthy limestone "Bottom Bed," with *Cardium rhæticum* | 0 | 4 |

The limestones above the Bottom Bed are used for building- and paving- purposes; the Bottom Bed and the "rubbish" are burnt for lime. Comparing this section with that at Strensham, we find a general correspondence in the lower beds. The strata at the time of my visit were exposed along a quarry-face extending East and West. The soil was a reddish-brown sandy clay with quartz and other pebbles, and the top limestone-bands were nipped up and broken along the successive folds, as if by Glacial agency. The soil was evidently in part the relics of a Drift accumulation. The disturbances are similar to those seen in a quarry near Littleton, Evesham, and probably like the contorted beds (of Rhætic limestone) noted by Strickland in the railway-cutting at Dunhampstead.

Strickland published, in 1840, accounts of the railway-cuttings between Ashchurch and Dunhampstead, and as early as 1834 he had mapped out the boundary of the Lower Lias in Worcestershire.* His observations led him to the conclusion that there were at least five well-marked successions in the Molluscan fauna of the Lias, in the district extending from the Worcestershire borders to Cheltenham, ranging through a thickness of five or six hundred feet, and unaccompanied by any change in the mineral character of the deposit.†

Higher beds of Lower Lias belonging to the zones of *Ammonites angulatus* and *A. Bucklandi* stretch across the country from Down Hatherly towards Stoke Orchard. At Piff's Elm, Boddington, limestones were formerly quarried, and there *Lima gigantea* and *Cardinia ovalis* were met with.‡

The region from Cheltenham northwards along the borders of Worcestershire and Warwickshire, is especially rich in species of *Cardinia*, and it appears likewise to have been the favoured

* Nat. Hist. of Worcestershire, by Dr. C. Hastings, 1834.

† Proc. Geol. Soc., vol. iii. p. 314; Trans. Geol. Soc., vol. vi. p. 551; Memoirs, p. 137.

‡ Brodie, Geologist, vol. i. p. 375.

home of *Hippopodium ponderosum.* Numerous specimens of *Cardinia Listeri* have been found at Down Hatherley, Defford, and Eckington, and *H. ponderosum* is recorded from the neighbourhood of Bredon and Great Comberton.

The fossils obtained by Strickland at Bredon, indicate the zones of *A. semicostatus* and *A. obtusus*, for he records *A. Turneri*, *A. Brookei*, *A. Birchii*, *A. obtusus*, and *A. planicosta*, also Rhyncholites, and fine examples of *Pleurotomaria.* Beds with *A. obtusus* have also been opened up on the west bank of the river Isborne, near Toddington, and at the reservoir near Childs Wickham.

A brickyard between Defford and Besford, north of the main road, showed about 15 feet of blue calcareous shale with small nodules of limestone and selenite. Here under the guidance of Mr. T. J. Slatter, I obtained *Ammonites semicostatus* (near the base), *Actæonina*, *Amberleya*, *Cerithium*, *Turritella Dunkeri*, *Pitonnillus*, *Avicula*, *Astarte*, *Cardinia Listeri* and var. *hybrida*, *Gryphæa cymbium*, *Rhynchonella*, *Acrosalenia*, and spines of Echinoderms. These species were identified by Messrs. Sharman and Newton. Strickland discovered remains of *Aptychi* at Defford.*

At Drake's Broughton, north-west of Pershore, a large number of fossils have been obtained by Mr. T. J. Slatter, of Evesham.† The precise locality is a brick- and tile- yard west of Pigeon House, where there was exposed about 10 feet of grey shaly clay, with small limestone-nodules and larger red ironstone-nodules. The assemblage of fossils is an interesting one; it appears to represent the zone of *Ammonites oxynotus*, although it includes species that elsewhere occur both at higher and lower levels. Among the fossils recorded are the following;—

| | |
|---|---|
| × Ammonites Birchii. | × Belemnites acutus. |
| —— Loscombei. | × Cardinia hybrida. |
| —— nodotianus. | —— crassissima. |
| × —— oxynotus. | × Hippopodium ponderosum. |
| —— Simpsoni. | Leda Zieteni. |
| × —— Slatteri. | × Rhynchonella variabilis. |

A number of Gasteropods, including species of *Cerithium*, *Actæonina*, &c., also *Dentalium*, have been found at this locality.

Of the species marked ×, examples were found during a visit I paid to the pit under the guidance of Mr. Slatter: they were named by Messrs. Sharman and Newton.

At the Atlas Works by Pershore Station, bricks are made, and the section showed a few feet of blue shaly and slightly calcareous clay, with occasional nodules of argillaceous limestone and ironstone. The beds are probably on a somewhat higher horizon than those exposed at Drake's Broughton; but fossils are

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* Quart. Journ. Geol. Soc., vol. i. p. 232, and Memoirs, p. 181.
† Wright, Lias Ammonites, p. 375.

not plentiful. I obtained *Ammonites Jamesoni*, *Belemnites*, *Gryphæa cymbium*, *G. arcuata*, and *Hippopodium ponderosum*.

Near Didcot Farm, north of Dumbleton Hill, a brickyard showed blue and brown marly clays, with many hard reddish ironstone-nodules and grey cement-nodules, layers of shelly limestone and thin shaly limestone. Among the fossils obtained were *Ammonites striatus*, *A. capricornus*, *Inoceramus ventricosus*, *Modiola scalprum*, *Pecten*, *Pholadomya ambigua*, *Pleuromya costata*, and *Unicardium cardioides*.* The beds represent the highest stage of the Lower Lias (zone of *Am. capricornus*).

* See also Wright, Proc. Cotteswold Club, vol. iii. p. 153.

# CHAPTER VI.

## LOWER LIAS—(*continued*).

### LOCAL DETAILS.

*Evesham to Stratford-on-Avon, the Vale of Moreton, Chipping Norton, aud Charlbury.*

IN the neighbourhood of Evesham the basement-beds of the Lower Lias occur near the surface at Hasler Hill, to the W.S.W. of the town, where stone was formerly quarried. A boring for coal by Hasler Farm, proved 75 feet of Lower Lias and Rhætic Beds, before the New Red Marl was reached.*

In the country north-east of Evesham, from South Littleton to Wilmcote, we find many sections of the basement-beds, which consist mainly of even beds of blue limestone and marl or dark shale. The shallow quarries now open near South Littleton and Cleeve Prior, to which I was conducted by Mr. R. F. Tomes, show only the bands of limestone (to a depth of 8 or 10 feet) that are used locally for building- and paving-purposes: we do not see the junction with the Rhætic Beds. At South Littleton the surface-beds were nipped up in a series of sharp folds as at Croome D'Abitot (p. 146).

At Cleeve Prior we find slabs (8 by 5 feet) with many specimens of *Ostrea liassica*, like the "Firestone" of Binton. Among other fossils are bones of *Ichthyosaurus*, also *Lima*, *Pleuromya*, species of Echini, &c. Banded limestone (Insect Limestone) yielding *Ammonites Johnstoni* was exposed in the Nibble quarry, east of Cleeve Prior.†

The thickness of the limestone-beds (zone of *Am. planorbis*) in this area is about 20 feet, for Strickland notes 34 feet of strata (including 14 feet of clay on top) down to the Firestone, at Bickmarsh, east of Cleeve Prior.‡

Sections, no longer well exposed, at Bidford, Binton, and Temple Grafton, have been described by Mr. R. F. Tomes and others. That at Binton is most important as it showed the connexion with the Rhætic Beds: the following account of it is by Mr. Tomes:—§

* Memoirs of H. E. Strickland, p. 88.
† See Tomes, Geol. Mag. 1888, p. 212.
‡ Memoirs, p. cc.
§ Quart. Journ. Geol. Soc., vol. xvi. p. 394, xxxiv. p. 182; Wright, Lias Ammonites, p. 19; and Brodie, Proc. Warwickshire Field Club, 1868.

| | | Ft. | In. |
|---|---|---|---|
| Lower Lias. | Paving-beds, finely laminated stone and shale, *Ammonites Johnstoni*, Insects, *Eryon barrovensis*, *Pholidophorus Stricklandi* | 16 | 0 |
| | Grizsley [or Grizzle] bed, composed of comminuted shells (*Lima* and *Ostrea liassica*), fish-scales, saurian bones, *Cidaris*, *Pentacrinus*, *A. Johnstoni* | 0 | 1 |
| | Blue Stone. Saurian remains rare. Insects | 0 | 7 |
| | Stone (unfossiliferous) | 0 | 6 |
| | Grave-stone bed. Saurian remains, *Otozamites acuminatus*, *Eryon barrovensis* | 0 | 5 |
| | Shale | 0 | 3 |
| | Pendles, hard crystalline stone. *Ostrea liassica* abundant | 0 | 1 |
| | Firestone, hard crystalline and shelly stone. *A. Johnstoni*, *Placunopsis alpina*, *Ostrea liassica* abundant, *Modiola minima*, *Pholadomya*, *Otozamites obtusus*, &c. | 0 | 8 |
| | Stone, impersistent | 0 | 1 |
| | Bottom blue stone, impersistent. *Monotis decussata* [or *fallax* ?] | 0 | 1 |
| | Shale | 0 | 3 |
| | Guinea-bed, hard and crystalline, so called because the stones, if dry, ring when struck. *Avicula cygnipes* (*longicostata*), *Monotis decussata* [?], *Cardinia*, *O. liassica*, *O. intusstriata*, *Placunopsis alpina*, *Axinus*, *Sargodon tomicus*, *Hemipedina Tomesi*, *Thecosmilia Terquemi*, &c. | 1 | 0 |
| Rhætic Beds. | Greenish-grey clay | 8 | 0 |
| | Maums or 'white lumps,' in all respects like the *Estheria*-bed of Westbury-on-Severn | 0 | 8 |
| | Clay of a greenish colour. | | |

Particular interest is attached to the "Guinea Bed," which was grouped, by Mr. Tomes, with the Rhætic Beds. I was unable to see it anywhere *in situ*, but there are two slabs in the Warwick Museum. One of these, a grey earthy and fossiliferous limestone with fissile cap, yielding *Hemipedina Tomesi*, was from Binton; and the other a grey shelly limestone, 2 to 2½ inches thick, and covered with *Ostrea liassica*, was from Wilmcote. Both specimens presented a Liassic rather than a Rhætic appearance. The fossils however that are recorded by Mr. Tomes from this bed at Binton, indicate an association of Rhætic and Lower Lias fossils; and as he tells me that the bed is sometimes conglomeratic, it seems likely that the fossils may be to some extent remanié.

A study of the Rhætic Beds leads to the conclusion that we are not far from a local margin of the deposit. There is a development of sandy beds, the black shales are very thin in places, and near Church Lawford they are absent; again, the White Lias north of Harbury is somewhat sandy, it shows current-bedding and ripple-marks, and is itself occasionally nodular, like the beds at Pinhay Bay near Lyme Regis. It is not improbable therefore that there was some irregular overlap of the Rhætic Beds, accompanied by re-construction of some layers, during the changing conditions that ushered in the Lower Lias. (*See* p. 141.)

The occurrence in the Guinea Bed of Binton, of *Avicula cygnipes* and *Hemipedina Tomesi* is strongly indicative of Lower Lias; moreover Dr. Wright records *Lima punctata* from the same bed. The *Monotis* he identifies as *M. fallax*. *Pleuromya crowcombeia*

(noted by Wright) occurs in both Rhætic Beds and Lower Lias. Of other species, *Sargodon tomicus* appears to be the only exclusively Rhætic fossil: nowhere else have we any record of its occurrence above the Black (*Avicula-contorta*) shales. Hence, regarding some of the fossils as "derived" specimens, the evidence favours the view that the Guinea Bed, at this locality, is the base of the Lower Lias, a position assigned to it by Wright, and also by Phillips.*

A section at Temple Grafton showed the higher beds of the zone of *Ammonites planorbis*, with Insect-limestones and Ostrea-beds below.†

The Lower Lias has been extensively quarried between Wilmcote and Newnham, to the north-west of Stratford-upon-Avon. The beds exposed, in 1889, in a quarry north-west of Gipsey (or Stone) Hall, Wilmcote, were as follows:—

| | | Ft. | In. |
|---|---|---|---|
| | Soil, with flints, &c. - - - - - - | 1 | 0 |
| Lower Lias. Zone of *Am. planorbis*. | Grey and blue clay - - - - - - | 10 | 0 |
| | Rusty clay - - - - - - - | 1 | 0 |
| | Clay and limestone-shale - - - - - | 5 | 0 |
| | Top Blocks. Pale earthy limestone - - | 0 | 6 |
| | Marly shale - - - - - - - | 3 | 0 |
| | Bottom Blocks. Pale blue-hearted earthy and banded limestone. *Ammonites Johnstoni* - - | 0 | 8 |
| | Marly shales with impersistent layer of limestone. *Lima gigantea*. Beds used for lime - - - | 2 | 6 |
| | Fine Course. Thin greyish-brown earthy limestone | 0 | 2 |
| | Marly shale - - - - - - - | 1 | 3 |
| | Whites. Hard blue-hearted limestone. Used for wall-stone and building-purposes - - - | 0 | 5 |
| | Marly shale. Saurian remains - - - | 1 | 4 |
| | Ribs or Bottom Rock. Hard blue-hearted banded limestone, used for building-purposes - - | 0 | 4 |
| | Blue and brown marly shales; the upper part more calcareous, and used for cement-making - - | 7 | 0 |
| | Marly limestone, hard blue limestones, and comminuted shelly layers, Cement Dirt; Lignite, Fish-remains - - - - - - | 1 | 6 |
| | Cement Beds. Thick Rock. Blue earthy limestones (2 beds) with Plant-remains - - - | 1 | 7 |
| | Pendles. Limestone-shales, used for Lump lime - | 5 | 6 |
| | Firestone. Ostrea-bed. Hard blue shelly limestone, with *Ostrea liassica*. Used for Lump lime - - | 0 | 3 |
| | Earthy limestone and shale. | | |

The higher beds of marly shale and leathery limestone-shale are discarded. The Top and Bottom Blocks are of no use for building, as they do not stand the weather.

At Wilmcote the layers on the whole are even-bedded. The banded beds are usually Insect Limestones, and they yield *Ammonites planorbis*, *A. Johnstoni*, *Glyphea Heeri*, *Eryon barrovensis*, and *E. wilmcotensis*. *Pholidophorus Stricklandi* is also recorded, and I obtained a specimen of *Ammonites rotiformis ?* and the bone of a *Plesiosaurus*.

* Geol. Oxford, p. 112.

† Tomes, Quart. Journ. Geol. Soc., vol. xxxiv. p. 184.

According to Dr. Wright, the Firestone consists of 3 beds, 1 ft. 2 in. thick, below which were 1 ft. of hard dark slaty shale, and then "the Guinea-bed," which he describes as a hard shelly limestone 1 inch thick; this rests on the Rhætic Beds.* The section which I have noted, was not exposed to a depth sufficient to show the beds beneath the Firestone; but a specimen of pale limestone with *Estheria* (in the Warwick Museum), was obtained at a depth of 4 feet below the Firestone. The details evidently vary a good deal, and it is by no means clear that the local names applied by the quarrymen, can be depended upon for correlation of particular beds in the different quarries; nor is it clear that the "Guinea-bed" is always on the same horizon, for in the section at Wilmcote the bed so-called, may represent the top band of the Rhætic Beds.

Outliers of Lower Lias occur south-west of Wootton Wawen, and south of Morton Bagot, near Henley-in-Arden. The Rev. P. B. Brodie has noticed Insect Limestone at Brown's Wood and Stooper's Wood, and mentions that the "Firestones" and "Guinea-bed" were formerly worked in the district.

An outlier more distant, between 10 and 11 miles from the main mass, occurs north of Knowle and south-west of Hampton-in-Arden. Attention was first called to this by Dr. Lloyd of Leamington. The stone was worked by means of shafts at Waterfield Farm and on Copt Heath.† Mr. Brodie has found Insect Limestones, and mentions that the Firestones and Guinea-bed were obtained from the old workings. No beds higher than the zone of *Ammonites planorbis* have been found, and Mr. Brodie notes this species, together with *Ostrea liassica, Modiola minima, Lima punctata,* spines of *Cidaris,* Fish-scales, and bones of *Ichthyosaurus*.‡

The higher beds of the Lower Lias near Evesham, consist mostly of clay, with occasional bands of limestone; and these include the zones of *Ammonites angulatus, A. Bucklandi,* and *A. semicostatus.*

Mr. T. J. Slatter informed me that the zone of *A. angulatus* was exposed in cuttings of the Midland railway, between Evesham and Hampton (Bengeworth station). *Cardinia ovalis* was abundant in places, and *C. hybrida* has also been found at Bengeworth. At a clay-pit (long since closed) east of Chadbury Farm, to the north of Evesham, the same beds were exposed. Fine specimens of *Cardinia ovalis* and *Isastræa Tomesi* were obtained by Mr. Slatter.

Mr. R. F. Tomes states that at Welford Hill near Stratford-on-Avon, *Isastræa* and "*Septastræa*" were associated with *Ammonites angulatus* and *Cardinia ovalis;* and that *A. angulatus* occurs upwards, through the clays yielding *A. semicostatus,* to the top of

* Quart. Journ. Geol. Soc., vol. xvi. p. 386; see also Brodie, Proc. Warwickshire Field Club, 1868; and Phillips, Geol. Oxford. pp. 105, 109.

† Strickland, Memoirs, p. 117.

‡ Warwickshire Nat. Hist. and Arch. Soc. 39th Ann. Report, 1875; Quart. Journ. Geol. Soc., vol. xxi. p. 159.

the zone in which *A. planicosta* and *Hippopodium ponderosum* appear.* This is certainly an unusual range for *A. angulatus.*

Bengeworth brickyard at Evesham showed a fine section of about 25 feet of dark shaly and ferruginous clay, covered with gravel, &c. Here may be found *Ammonites Charmassei, A. semicostatus, Pleurotomaria anglica, Avicula inæquivalvis, Cardinia Listeri* var. *hybrida, Gryphæa arcuata, Ostrea liassica, Lucina limbata, Extracrinus,* &c. The species were identified by Messrs. Sharman and Newton.

Eastwards, at Bretforton, the Lias was penetrated to a depth of 300 feet in search of coal. (See p. 300.)

At Sheekill's brickyard, Pebworth, we find about 8 feet of blue shaly clay, with small and large irregular nodules of argillaceous limestone, capped by brown clayey soil with Drift pebbles. The beds here are regarded, by Messrs. Tomes and Slatter, as the local zone of *Ammonites sauzeanus,* for that species is common: but it may be remarked that the forms approach closely to *A. bisulcatus.* Among other fossils are *A. semicostatus, Gryphæa, Mytilus,* and *Montlivaltia.*

Along the railway towards Shipston-on-Stour we find occasional cuttings in blue clay. That by the high road between the town and Chipping Campden, yielded *Ammonites semicostatus, Gryphæa arcuata,* and *Pecten.* The clay contains much selenite, and occasional bands and small nodules of limestone.

Honeybourne brickyard, near the railway-station, showed about 10 feet of blue shaly and slightly calcareous clay, with rusty bands, and irregular nodules of limestone and ferruginous concretions. The clay was contorted in places, probably by Glacial action, as is the case with beds exposed at the surface north of this region. The fossils found here include:—

| | |
|---|---|
| Ammonites bisulcatus. | Hippopodium ponderosum. |
| —— Brookei. | Gryphæa. |
| †—— densinodus. | Lima. |
| †—— raricostatus. | Mytilus. |
| —— Turneri. | †Montlivaltia rugosa. |

The beds belong to the same horizon as those exposed at Marle Hill, Cheltenham. (See p. 143.) Fine specimens of *Pleurotomaria* were obtained by Mr. J. Windoes from this locality. *Ammonites raricostatus* has been recorded from the neighbourhood of Ilmington, and *Hippopodium ponderosum* from Todenham.

The cutting on the Great Western Railway at Aston Magna, revealed Lower Lias clay and shale containing *Ammonites armatus, Belemnites, Pleurotomaria anglica, Leda, Plicatula spinosa, Spiriferina verrucosa, Waldheimia numismalis,* and other fossils, forming an assemblage that may be parallelled with that obtained from the zones of *Ammonites Jamesoni,* &c., by Mr. Beesley at Fenny Compton. The beds at Aston Magna were described by

* Quart. Journ. Geol. Soc., vol. xxxiv. p. 179; see also Moore, *Ibid.*, vol. xxiii. p. 511.

† Given on the authority of Mr. R. F. Tomes: the other species were named by Messrs. Sharman and Newton.

Mr. G. E. Gavey in 1853;* subsequently many fossils were obtained by Mr. T. J. Slatter, and the species have been recorded by Prof. R. Tate.† They include the following:—

| | |
|---|---|
| Ammonites armatus. | Hippopodium ponderosum. |
| —— fimbriatus. | Leda (acuminata) Zieteni. |
| —— raricostatus (coll. J. Jones). | —— complanata. |
| Belemnites clavatus. | —— subovalis. |
| —— compressus. | Lima scabricula. |
| —— umbilicatus. | Limea acuticosta. |
| Actæonina marginata. | Modiola numismalis. |
| Cerithium camertonense. | Nucula cordata. |
| —— Slatteri. | Plicatula spinosa. |
| Chemnitzia Blainvillei. | Venus (Ceromya) bombax. |
| —— (?) liassica. | Rhynchonella variabilis, var. bidens. |
| Exelissa (Kilvertia) numismalis. | —— furcillata. |
| Trochus Thetis. | Spiriferina verrucosa. |
| Turbo admirandus. | Waldheimia indentata. |
| —— cyclostoma (?). | —— numismalis. |
| Anatina numismalis. | Pentacrinus basaltiformis. |
| Arca Stricklandi. | Ditrupa etalensis. |
| —— numismalis. | Serpula plicatilis. |
| Astarte amalthei. | —— subpentagona. |
| Gervillia lævis. | |
| Gryphæa cymbium. | |

A full and interesting account of the railway-cuttings at the Mickleton Tunnel, near Chipping Campden, was published also in 1853 by Mr. Gavey.‡ The hill above Mickleton Tunnel rises to an elevation of 490 feet, and is formed of Lower Lias and Middle Lias shales and clays, overlaid by Marlstone and Drift. The Drift proved to be 76 feet thick, and consisted of loamy sand and gravel, and red clay with blocks of Marlstone.

Beds of Lias shale upwards of 80 feet thick were exposed. The upper portions contained nodules and slabs of ironstone, and thin beds of sandstone, and these yielded a number of Echinodermata, including *Uraster Gaveyi*, *Tropidaster pectinatus*, and *Ophioderma*, together with *Ammonites* and other fossils. The general list published by Mr. Gavey shows that Middle and Lower Lias were exposed: and the beds correspond with those opened up in the railway-cutting near Chipping Norton. The fossils just mentioned probably belong to the Middle Lias (zone of *Ammonites margaritatus*). The lower portions of the clays belong to the zone of *A. capricornus* (or *A. Henleyi*), and probably to lower beds, as indicated by the presence of *A. planicosta*, &c. Prof. Hull mentions the occurrence of *Hippopodium ponderosum*. Layers of crushed oysters were noticed by Mr. Gavey, also plant-remains and large pieces of carbonized wood. Of this lignite, he remarks that "one piece was about 7 feet long, and more than 1 foot wide, but, being in a crushed state, it was only 1½ inch thick; it was converted into jet. Other pieces were of a dark brown colour, impregnated with iron-pyrites."

A deep boring made at Mickleton Wood, near Chipping Campden, for Mr. S. G. Hamilton, of Kiftsgate Court, has proved

* Quart. Journ. Geol. Soc., vol. ix. pp. 35, 36.
† *Ibid.*, vol. xxvi. pp. 396–399.
‡ Quart. Journ. Geol. Soc., vol. ix. pp. 29–33; see also E. Hull, Geol. Cheltenham, p. 17; and Decade III., Geol. Survey.

a greater thickness of Lower Lias than is known elsewhere in this country. The boring, which was commenced in the Middle Lias, was carried through the Lower Lias, and Rhætic Beds, into the Keuper Marls. It was originally undertaken with the object of finding water, and when no supply was obtained, Mr. Hamilton resolved to continue the boring as a scientific enterprise; but it was abandoned soon after the Keuper Marls were reached. The work was carried out by Messrs. Le Grand and Sutcliff (1890–92) and the following are the particulars of the strata passed through:—

## SECTION AT MICKLETON, GLOUCESTERSHIRE.

[Old Dug Well, 45 feet; the rest bored. Cores 8 inches to 2 inches in diameter.]

| | | THICKNESS. Ft. | In. | DEPTH. Ft. | In. |
|---|---|---|---|---|---|
| Middle Lias. 280 feet. | Marlstone: ferruginous earthy limestone, with *Cardium*, *Modiola scalprum*, and *Pinna* - - | 36 | 0 | | |
| | (Beds not noted: portion of old dug well) - - - - | 9 | 0 | 45 | 0 |
| | Hard bluish-green rock - - | 13 | 0 | 58 | 0 |
| | Loamy sand and stone - - | 3 | 0 | 61 | 0 |
| | Hard sand, with bands of stone - | 19 | 0 | 80 | 0 |
| | Blue shale and clay - - - | 13 | 0 | 93 | 0 |
| | Blue stone - - - - - | 3 | 0 | 96 | 0 |
| | Brown rocky sand - - - | 5 | 0 | 101 | 0 |
| | Hard blue marly clay, with nodular limestone, and iridescent shells: *Ammonites fimbriatus*, *Cardium truncatum*, *Modiola scalprum*, and Crustacean - - - | 179 | 0 | 280 | 0 |
| Lower Lias. 961 feet. | Hard blue marly clay, with occasional nodules of limestone, and iridescent shells: *Ammonites capricornus*, and *Pleuromya costata* - | 249 | 0 | 529 | 0 |
| | Hard blue clay, with bands of stone - | 3 | 0 | 532 | 0 |
| | Hard blue clay and shells: *Ammonites*, *Amberleya*, *Cryptænia*, *Gryphæa arcuata*, *Inoceramus ventricosus*, and *Unicardium* ? (crushed)- - - | 296 | 0 | 828 | 0 |
| | Limestone - - - - - | 3 | 6 | 831 | 6 |
| | Hard black shaly clay - - - - | 5 | 6 | 837 | 0 |
| | Hard clay, with shells: *Ammonites semicostatus* at depth ef 870 - - | 63 | 0 | 900 | 0 |
| | Limestone - - - - - | 4 | 0 | 904 | 0 |
| | Clay ,with shells - - - - - | 12 | 0 | 916 | 0 |
| | Limestones, marly clay, and shells, *Am. semicostatus* at 920 and 977 - | 76 | 0 | 992 | 0 |
| | Limestones and marls with shells: Encrinite stem at 1000; blue limestone and dark shales at 1073 - | 92 | 0 | 1084 | 0 |
| | Limestones with *Ammonites angulatus*, *A. Charmassei*, and *Rhynchonella calcicosta* - - - - - | 8 | 0 | 1092 | 0 |
| | Limestones and marls, with occasional shells - - - - - | 44 | 0 | 1136 | 0 |
| | Pale limestone - - - - - | 0 | 2 | 1136 | 2 |
| | Limestone - - - - - | 12 | 10 | 1149 | 0 |
| | Blue shaly limestone with *Cardinia* and *Lima* - - - - - | 6 | 0 | 1155 | 0 |
| | Limestones, freer cutting - - | 86 | 0 | 1241 | 0 |

| | | Thickness. Ft. | In. | Depth. Ft. | In. |
|---|---|---|---|---|---|
| Rhætic Beds. 74 feet | Pale grey limestone, with pyrites | 11 | 0 | 1252 | 0 |
| | Brown and grey clays, and black shales, with *Avicula contorta*, *Isodonta Ewaldi*, *Pecten valoniensis*? *Gyrolepis Alberti*, and *Saurichthys acuminatus* - - - - - | 33 | 0 | 1285 | 0 |
| | Grey and blue marls, with layer of sandstone at 1307, and under it a thin vein of brown plastic clay - | 30 | 0 | 1315 | 0 |
| Keuper Marls 27 feet. | Green and red marls, in hard and soft bands - - - - - | 15 | 0 | 1330 | 0 |
| | Red marl with band of red sandstone at top; and trace of gypsum near bottom - - - - - - | 12 | 0 | 1342 | 0 |

Specimens of the strata and fossils were forwarded to the Museum at Jermyn Street, by Mr. Hamilton, and also by Messrs. Le Grand and Sutcliff, to whom I am indebted for the above record. The fossils were named by Messrs. Sharman and Newton.

In addition to the species mentioned, some others were sent without records of depths: they include *Arca Stricklandi*, *Cypricardia intermedia*, and *Pecten Thiollieri*, probably from the base of the Middle Lias. A specimen of *Ammonites planorbis* was stated to come from a depth of 850 feet. The actual junction of Lower and Middle Lias cannot be determined within about 20 feet, and the record now given differs from that published in several newspapers by Messrs. Le Grand and Sutcliff, as a number of fossils have since been examined, which enable the junction to be determined within nearer limits, and to reduce the former estimate of the thickness of the Lower Lias.

The total thickness of the Lias in this neighbourhood may be reckoned at 1,360 feet, as the Upper Lias clay has been estimated at 120 feet by Mr. Hamilton. Nowhere else in this country has so great a thickness of the strata been ascertained, for even in Yorkshire the measured sections of the Lias show a full thickness of under 1,100 feet.

At Cherrington, in shelly limestone belonging to the zone of *Ammonites capricornus*, numbers of the large Coral, *Montlivaltia Victoriæ*, were found by Messrs. Tomes and Slatter. One other locality is known where they occurred in equal profusion, and that is the water-works at Grimsbury, Banbury, where Mr. Beesley informed me they were even more abundant than at Cherrington.

A large collection of fossils was obtained by the Rev. S. Lucas, from the cutting on the Banbury and Cheltenham Railway at Mangersbury, near Oddington. The zone of *Ammonites Henleyi* and other beds were exposed, but the horizons of the fossils recorded are not indicated.* A well sunk at Bliss's Factory, Chipping Norton, proved 500 feet of Lias, chiefly clay belonging to the Lower Lias and lower part of the Middle Lias. The sinking was abandoned, as no water was obtained.†

* Geologist, vol. v. p. 127.
† *Ibid.*, p. 128; and Rev. J. Clutterbuck, Journ. R. Agric. Soc., vol. i. p. 282.

During the construction of the railway-tunnel at Chipping Norton, many fine fossils were obtained by Mr. James Windoes of that town, from the zones of *Ammonites capricornus* and *A. margaritatus*. Among those obtained from the zone of *A. capricornus*, were the following :—

Ammonites capricornus.
—— Davœi.
—— Henleyi.
—— fimbriatus.
Belemnites elongatus.
—— vulgaris.
Amberleya imbricata.
Avicula inæquivalvis.
Cypricardia intermedia.
Goniomya hybrida.
Gresslya.
Hippopodium ponderosum (smooth var.).
Inoceramus ventricosus.
Modiola scalprum.
Pleuromya costata.
Pholadomya ambigua.

The specimens of *Cypricardia intermedia* (a form that approaches very near to *C. cucullata*) were exceptionally well preserved, the finer and larger specimens coming from the zone of *A. margaritatus*. In a long list of fossils from the Lias of this locality, Mr. Beesley* has not separated the species procured from the two zones, because the fossils were mainly collected from the material brought up from the shafts, or carried out at the mouths of the tunnel. Mr. Windoes obtained a portion of *Ammonites Henleyi* belonging to a specimen 18 inches in diameter.

The observations of Mr. F. A. Bather furnish evidence of the zone of *Ammonites capricornus* near Fawler.† At this locality blue clay with hard nodules and a few septaria was proved, by a boring, to a depth of 120 feet. In the upper part of this clay *A. margaritatus* was found, and slightly below, *A. capricornus*.

Beds with *Amm. capricornus*, &c. were proved in a boring at Burford Signett, at depths of from 270 to 300 feet from the surface. The total thickness of the Lower Lias proved to be about 450 feet, and that of the Middle Lias nearly 100 feet; the thickness of the former being less than one half of that at Chipping Campden. Limestones are not very prominently developed at the base of the formation, for the record of the boring gives clay with occasional bands of limestone to near the bottom of the Lias.‡

The cutting of the Great Western Railway near Charlbury, yielded *Ammonites planicosta* and *Pleurotomaria anglica*;§ while at Ascott-under-Wychwood "the skeleton of an *Ichthyosaurus* was found." Here, according to Prof. Hull, the beds "consist of

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* Proc. Warwickshire Field Club, 1876, p. 30; Proc. Geol. Assoc., vol. v. pp. 181-184; see also Wright, Lias Ammonites, Palæontograph. Soc., p. 433.
† Quart. Journ. Geol. Soc., vol. xlii. p. 144.
‡ See Etheridge, Pop. Sc. Review, ser. 2, vol. iii. p. 290; and De Rance, Rep. Brit. Assoc. for 1878. Details of the Burford boring will be given in a subsequent volume on the Oolitic rocks.
§ W. S. Horton, Geologist, vol. iii. p. 251.

bluish shales, weathering grey and brown, with small nodules of earthy limestone and iron-concretions."*

*Kineton, Harbury, Fenny Compton, and Banbury.*

Turning again to the beds in Warwickshire, we find the Lower Lias limestones exposed in the railway-cuttings between Stratford-on-Avon and Eatington. The beds, as remarked by the Rev. P. B. Brodie, are much disturbed in places, but near the station north of Upper Eatington "the Lima and other beds are exposed in a cutting about 60 feet deep, consisting of the usual series of bands of limestone divided by shales." The beds dip in an easterly direction.

At Kineton the railway-cuttings again show limestones, in places disturbed and broken. Thirty-two bands of blue limestone divided by shale, having a total thickness of 60 feet, were noticed by Mr. Brodie, and the fossils include *Ammonites angulatus, Lima Hermanni, L. gigantea, Gryphæa arcuata, Pecten pradoanus*, and *Rhynchonella calcicosta*.†

We have thus in this neighbourhood, a development of limestones belonging to the zone of *Ammonites angulatus*, beds which are for the most part represented by clay near Evesham.

At Harbury, between the railway-station and Bishops Itchington, there are extensive lime-works belonging to Messrs. Greaves, Bull, and Lakin. The limestone is used in the Blue Lias lime-and cement-works, the clay not being required. The quarries, opened to a depth of about 45 feet, show alternating bands of bluish-grey limestone (upwards of 30 in number), and marly clay and shale, the latter being a little thicker on the whole. There is much pyrites in the shales, and the bands of stone are iron-stained on the joints. The fossils obtained here, include *Ammonites angulatus, Gryphæa arcuata* (small specimens abundant), *Lima gigantea, Plicatula, Rhynchonella calcicosta*, and *Plesiosaurus (Eretmosaurus) rugosus*.‡

The lowest beds of the Lias are not well exposed in the railway-cutting, but beneath the series of limestones which are shown between the railway-station and the tunnel on the north, there is some thickness of blue clays, which rest on the White Lias. In the railway-cutting the following beds may be seen:—

| | | Ft. | In. |
|---|---|---|---|
| Lower Lias | 40 or 50 bands of limestone, alternating with clay or shale - - - - about | 50 | 0 |
| | Blue clays and shales (not well exposed) about | 30 | 0 |
| Rhætic Beds. | White Lias, &c. | | |

* Hull, Geol. Woodstock (Mem. Geol. Survey, Sheet 45, S.W.), p. 9.

† Warwick Nat. Hist. and Arch. Soc., 1875, 39th Ann. Report, pp. 6, 7.

‡ Recorded in Proc. Geol. Assoc., vol. ii. p. 285; Brodie, Warwick Nat. Hist. and Arch. Soc., 39th Ann. Report, 1875.

The beds were measured, in 1873, by the Rev. P. B. Brodie and Mr. T. Beesley, and details (differing in some particulars) have been published by them. The fossils indicate that the lower portion of the zone of *Ammonites Bucklandi*, and the zone of *A. angulatus*, are represented by the limestone-series. The Insect Limestones do not appear, the limestones of this division and of the zone of *A. planorbis* generally, being represented, so far as can be observed, by clay, which is a very unusual feature.

The following fossils have been obtained from the railway-cutting at Harbury:—

| | |
|---|---|
| Ichthyosaurus. | Ostrea liassica. |
| Plesiosaurus. | Pecten lunularis. |
| Acrodus. | —— pradoanus. |
| Ammonites angulatus. | Perna. |
| —— Bucklandi. | Pinna. |
| —— Conybearei. | Pholadomya glabra. |
| —— Johnstoni. | Unicardium cardioides. |
| Nautilus striatus. | Rhynchonella calcicosta. |
| Avicula inæquivalvis. | —— plicatissima. |
| Gryphæa arcuata. | Cidaris Edwardsi. |
| Lima Hermanni. | Extracrinus briareus. |
| —— gigantea. | Pentacrinus tuberculatus. |
| Ostrea irregularis. | |

The limestones (zones of *Am. angulatus* and *A. Bucklandi*) have been worked for lime at Southam, Stockton,* Long Itchington, Draycote near Bourton-upon-Dunsmore, and Stretton-upon-Dunsmore. A specimen of *Hemipedina Tomesi* (in the Warwick Museum) was obtained from a grey and rather compact limestone at Long Itchington. This is indicative of the basement-beds of the Lower Lias.

The clays above the stone-beds have been worked for brick-making south-east of Southam, and also at the base of Napton Hill, to the east of Southam, where the beds belong to the zone of *A. capricornus*.

The boundaries between the Keuper Marls, Rhætic Beds, and Lower Lias, can be readily determined as far as the neighbourhood of Stretton-on-Dunsmore; but further north the beds are much obscured by Drift.†

The railway-cutting south of Fenny Compton railway-station, has shown an excellent section of the beds from the base of the zone of *Ammonites Henleyi*, through that of *A. Jamesoni* and *A. Ibex*, into that of *A. armatus*. These beds and their fossil contents have been very fully described by Mr. Thomas Beesley, and as the section is now by no means so clear as it was, I append his account, merely observing that I visited the section in 1887 under his guidance. The following is the section by Mr. Beesley‡ :—

* See Warwicksh. Nat. Field Club, 1877, p. 34, and 1881, p. 8.

† Howell, Geology of Warwickshire Coal-field (Mem. Geol. Survey), p. 45.

‡ Proc. Warwickshire Nat. Club, 1877, pp. 1-22; see also R. Tate, Quart. Journ. Geol. Soc., vol. xxxi. p. 509.

| | | Ft. | In. |
|---|---|---|---|
| Lower Lias. Zones of *A. Ibex*, *A. Jamesoni*, and *A. armatus*. | 13. Rough shaly clay - - - - - | 20 | 0 |
| | 12. Band of calcareo-argillaceous nodules - | 0 | 2 |
| | 11. Shale - - - - - - - | 10 | 0 |
| | 10. Band of nodules, with *Am. Henleyi*, *A. Ibex*, *A. Maugenesti*, and *A. Valdani* - - | 0 | 3 |
| | 9. Shale - - - - - - | 8 | 0 |
| | 8. Band of nodules, with *Am. Maugenesti* and Fucoids - - - - - - | 0 | 2 |
| | 7. Shale, with *Belemnites* - - - | 2 | 0 |
| | 6. Rough, shelly, argillaceous limestone, with *Am. Valdani*, *A. Jamesoni*, *Spiriferina verrucosa*, *Belemnites clavatus*, *Lima hettangiensis*, *Waldheimia numismalis*, and *Rhynchonella rimosa* - - - - - - | 1 | 0 |
| | 5. Shale, with *Belemnites* - - - | 4 | 6 |
| | 4. Rough, shelly, argillaceous limestone, with *Am. armatus* (young), *Pecten priscus*, *Limea acuticosta*, *Gryphæa obliquata*, *Cardinia attenuata*, *Rhynchonella rimosa*, *Montlivaltia mucronata* - - - - - - | 0 | 9 |
| | 3. Shales with band of nodules - - - | 4 | 11 |
| | 2. Band of nodules, with *Pecten calvus*, *Waldheimia subovoides* - - - - | 0 | 3 |
| | 1. Shales with bands of nodules - - | 45 | 0 |
| | | 97 | 0 |

Long lists of the fossils (including more than 300 species) have been published by Mr. Beesley, who has grouped the beds generally under the zone of *Ammonites Jamesoni*, because he found it impossible to fix the precise horizon of the majority of the specimens. He obtained about 2,000 Belemnites, among which he has recognized about 63 species. It may be remarked that he obtained only one example of *Ammonites Jamesoni* and that an imperfect one. *A. Valdani* is more abundant, but *A. latæcosta*, mentioned in his lists, is a doubtful identification.

Among the more abundant fossils not mentioned above, are *Belemnites lævis*, *Avicula inæquivalvis*, *Gryphæa arcuata*, *Plicatula spinosa*, *Pentacrinus scalaris*, and *Serpula*.

At the waterworks at Grimsbury, many fossils were obtained by Mr. Beesley, especially in a stone-band which appears to be local. Here the Coral, *Montlivaltia Victoriæ*, was found in great numbers, as at Cherrington; *Spiriferina rostrata* was numerous, and *Ammonites latæcosta* has also been recorded.

The Brickyard south of Grimsbury, just north of the railway-stations at Banbury, showed about 15 feet of bluish micaceous sandy clay, at the base of which there is a layer of shelly limestone, about 1 foot thick, known as the Banbury Marble, which rests on blue shale. This stone was not exposed at the time of my visit (1887), as water rises when it is reached and prevents deeper working; it is however described by Prof. A. H. Green, and a specimen was kindly procured for the Museum of Practical Geology, by Mr. E. A. Walford. The clay yields *Ammonites striatus*, *A. Loscombei*, *Belemnites*, *Amberleya*, *Unicardium cardioides*, *Pleuromya costata*, *Inoceramus ventricosus*, *Goniomya*

*hybrida*, *Modiola scalprum*, *Leda complanata*, *Pholadomya ambigua*, and *Myoconcha* (near to) *decorata*.* The Marble, which had been dug up near the L. & N. W. Railway station, yields *Gryphæa cymbium*, *Pecten textorius*, *Hippopodium ponderosum*, *Cardinia hybrida* (recorded also from the clay), and *Ammonites fimbriatus*. These fossils were identified by Messrs. Sharman and Newton.

North of the road N.W. of Nethercote, there is a brickyard showing bluish-grey and brown micaceous clay, with at the base a shelly clay with crinoidal remains; still lower there is a band of blue shelly limestone, ferruginous nodules and cement-stones, about 1 foot thick. This is no doubt the equivalent of the Banbury Marble; it contains *Pecten*, *Gryphæa*, *Inoceramus ventricosus*, and *Cardinia*, while *Ammonites Henleyi* occurs in the clay. Blue clay occurs at the base of the Marble, and clay belonging to the same zone, has been opened up at Warkworth, as noted by Prof. Green.

North-east of the Nethercote brickyard, there is an old pit showing sandy beds overlying bluish-grey micaceous clays. These probably belong to the zone of *Ammonites margaritatus*.

North-west of Aynho Station there is a brickyard showing blue and brown clays with ironstone nodules. I could find no fossils, but the beds probably belong to the zone of *Ammonites capricornus*. Much of the area mapped as Lower Lias in the neighbourhood of Deddington, belongs however to the Middle Lias (zone of *Ammonites margaritatus*), from the fact that the boundary between Lower and Middle Lias was taken at the top of the stiff clays, which include portions of the zone of *A. margaritatus*.

## *Rugby.*

The lower beds of the Lower Lias have been exposed in a cutting on the Rugby and Birmingham railway (by the 87th milestone), west of Church Lawford. The section was as follows:—

| | | |
|---|---|---|
| Lower Lias. | Paper shales, with much pyrites and selenite, small nodules of tough earthy limestone, and numerous spines of Echini - - - - - | about 20 feet. |
| Rhætic Beds. | Compact blue-hearted and buff limestone, with hard nodules or pebbles of limestone at top, in places - | 5 to 6 feet. |
| | Hard buff limestones, fissile in places, and much iron-stained - - - - - - | |
| | Greenish-grey marl - - - - - | 5 to 8 feet. |
| Keuper. | Red and green marls. | |

The paper-shales that here constitute the base of the Lower Lias, present a striking resemblance to the black paper-shales (*Avicula-contorta* beds) of the Rhætic series; and it is noteworthy that the latter are not represented at this locality. Here however, as at Harbury, the calcareous element is poorly developed in the basement-beds of the Lower Lias.

* Lists of fossils have been published by A. H. Green, Geol. Banbury (Mem. Geol. Survey, Sheet 45), p. 5; and T. Beesley, Proc. Warwickshire) Field Club, 1872.

*Ammonites planorbis* has been recorded from Church Lawford and Kings Newnham;* and in the British Museum there is a huge specimen, 39 inches in diameter, regarded as *Ammonites planorbis*, which was obtained from one of the Rugby quarries. This would have come from a somewhat higher horizon, about the base of the zone of *A. angulatus*.

Probably the finest inland section of the Lower Lias limestones, is that at the Victoria quarry, about a mile north-west of Rugby, at the Rugby Blue Lias lime- and cement- works. Here we see in one face, upwards of 35 bands of limestone, with alternating beds of blue shale and clay. The top layers are brown, but the mass of the beds is blue. The limestones vary from about 3 in. to 1 ft. or more in thickness, and most of them have a local name known to the quarrymen (see p. 296). The clays vary from a few inches to 4 ft. in thickness; a band 4 ft. thick occurring near the base of the quarry. The beds opened up attain a thickness of over 70 feet. Particular layers of stone and clay are used in the manufacture of cement, but the mass of the clay is rejected.

The following are the more abundant fossils obtained:—

| | |
|---|---|
| Ichthyosaurus. | Avicula inæquivalvis. |
| Plesiosaurus. | Gryphæa arcuata (and varieties like *G. cymbium*). |
| Fish-remains. | Lima gigantea. |
| Ammonites angulatus. | Modiola minima. |
| —— Bucklandi. | Pleuromya costata. |
| —— Conybearei. | Rhynchonella calcicosta. |
| —— Johnstoni. | Pentacrinus. |
| —— rotiformis. | |

Some of the Ammonites in the lower shaly beds are pyritic.

The large pit north of Newbold Grange, at the Newbold lime- and cement- works, shows about 45 feet of blue shales and grey argillaceous limestones, more clayey and browner in colour towards the top. There are about 30 beds of limestone. The beds are bent into a sharp anticlinal, shown on the north-eastern side of the pit, but they appear to recover their horizontality at short distances on either side. (See Fig. 52, which has been prepared from a photograph kindly sent me by Mr. J. D. Paul.) Thin accumulations of Drift sand and gravel, with pebbles of quartz and quartzite, occur on top in places.†

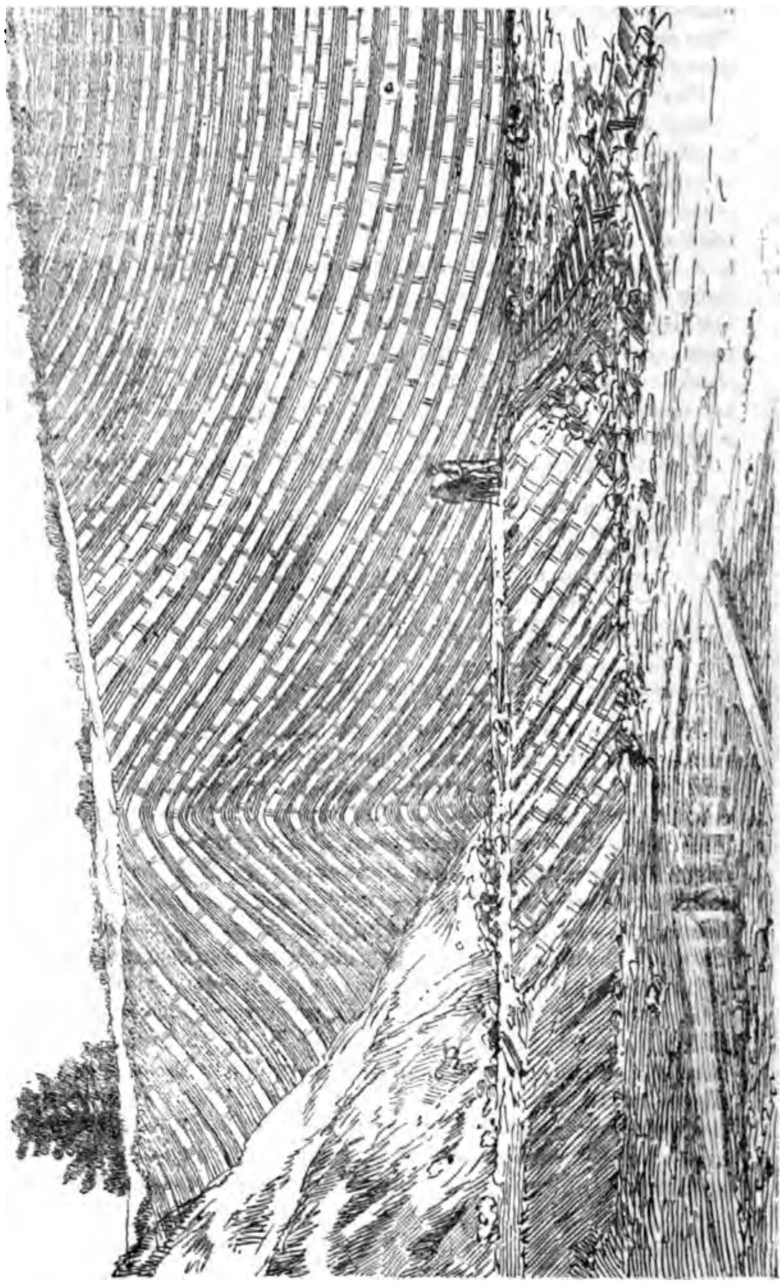
Nearer Rugby than the Victoria quarry, there are at New Bilton several brickyards, showing from 15 to 25 feet of blue clay with an occasional band of argillaceous limestone, overlaid in places by 10 feet or more of gravel and sand. The depth to the limestones is from 30 to 50 feet according to the situation. Fossils are by no means abundant in these clays, but I obtained a few specimens, indicating the zone of *Ammonites semicostatus*:—

| | |
|---|---|
| Ammonites semicostatus. | Gryphæa arcuata. |
| Pleurotomaria. | —— cymbium. |
| Avicula inæquivalvis. | |

* Report Rugby School Nat. Hist. Soc. for 1877, p. 48.

† See Horizontal Section (Geol. Survey), Sheet 140, and Explanation, p. 9.

FIG. 52 *Quarry at Newbold, Rugby.*



Lower Lias limestones, showing anticline trending east and west.

At Hill Moreton there are brickyards showing about 20 feet of bluish-grey clay with small limestone-nodules, and with gravel and sand on top. From this locality I obtained the following fossils, which were named by Messrs. Sharman and Newton:—

| | |
|---|---|
| Belemnites. | Turritella Dunkeri. |
| Ammonites brevispina. | Arca Stricklandi. |
| —— guibalianus. | Gryphæa arcuata. |
| —— semicostatus. | —— cymbium. |
| —— subplanicosta. | Unicardium cardioides. |

Bones of *Ichthyosaurus*, *Ammonites armatus*, *A. Birchii*, *A. oxynotus*, and *Hippopodium ponderosum*, have been recorded from this locality; while a bed with *Montlivaltia rugosa*, has also been observed, both here and at Catthorpe.* The fossils here indicate beds from the zones of *A. obtusus* to *A. Jamesoni*; and the beds may be compared with those opened up in the Cheltenham Gas-works (p. 143), Marle Hill at Cheltenham, Drake's Broughton, and Honeybourne. The occurrence of *A. semicostatus* is noteworthy, but that species is recorded by Dumortier from the zone of *A. oxynotus*.†

A deep well made to the south east of Rugby, proved the following beds of Lower Lias:—‡

| | | | Ft. | In. |
|---|---|---|---|---|
| Glacial Drift | | Red sand and gravel | 10 | 0 |
| Lower Lias | 11. | Blue clay with a band of limestone | 119 | 0 |
| | 10. | Limestone | 4 | 0 |
| | 9. | Clay | 6 | 0 |
| | 8. | Alternate bands of clay and limestone | 11 | 0 |
| | 7. | Clay with four bands of limestone | 53 | 0 |
| | 6. | Alternate bands of clay and limestone | 147 | 9 |
| | 5. | Clay | 6 | 0 |
| | 4. | Limestone | 4 | 0 |
| | 3. | Clay | 27 | 3 |
| | 2. | Stone | 12 | 0 |
| | 1. | Blue, brown, and black clay | 68 | 0 |
| Rhætic Beds | | Very light hard stone (White Lias) | — | |
| | | | 468 | 0 |

Judging from this record beds 1, 2, and 3 include the beds exposed near Church Lawford—representing the zone of *Ammonites planorbis*, with a thickness 107 feet 3 inches. Beds 4, 5, and 6 include the stone worked in the Lime-quarries, representing the zones of *A. angulatus* and *A. Bucklandi*, with a thickness of 157 feet 9 inches. Beds 7, 8, 9, and 10 may be taken to include the clays of New Bilton, and to represent the zone of *A. semicostatus*; while Bed 11 no doubt includes the clays of Hill Moreton, which represent the zones of *A. obtusus*, *A. oxynotus*, and *A. raricostatus*.

The well was carried to a depth of 1,145 feet into the Keuper "Water-stones," but was unsuccessful, as the water proved to be saline.

* See E. Cleminshaw, Rep. Rugby School Nat. Hist. Soc. for 1867, p. 36; also Reports for 1872, p. 47, 1874, p. 8, and 1877, p. 46.

† Etudes pal. Dépôts Jurassiques, Bassin du Rhône, vol. ii. p. 102.

‡ See J. M. Wilson, Report Rugby School Nat. Hist. Soc. for 1868, p. 41, and Rep. for 1874, p. 71.

At Clifton, near Rugby, blue clays and sands were sunk through to a depth of 132 feet: the greater portion of the beds being Glacial Drift.*

The brickyard at Braunston, situated on the north side of the canal, S.S.E. of the church, showed about 20 feet of bluish-grey clay with small cement- and ironstone- nodules, capped by gravel. Here I obtained the following fossils indicative of the zone of *Ammonites Jamesoni*:—

| | |
|---|---|
| Ammonites striatus. | Inoceramus ventricosus. |
| —— Valdani. | Gryphæa sp. |

Blue clay is exposed by the canal north of Willoughby Wharf, north of Braunston, and there *Unicardium cardioides* and some other fossils have been obtained.† *Ammonites Henleyi*, *A. Ibex* and *Inoceramus ventricosus* have been recorded from the Kilsby tunnel,‡ and *A. capricornus* has been found in a railway-cutting at Crick.§

A number of Foraminifera, from a brick-pit near Welton railway-station, have lately been described by Messrs. W. D. Crick and C. D. Sherborn. The clays at this spot evidently occur at the junction of the Lower and Middle Lias, for among the fossils recorded are *Ammonites Valdani*, *A. trivialis*, *A. margaritatus*, and *A. Engelhardti*.||

In the country near Daventry, as near Banbury, the junction between Lower and Middle Lias, has been drawn on the Geological Survey maps mainly on the evidence of physical features, lines of springs being taken to mark the upper limit of the Lower Lias beneath the more porous sandy shales of the Middle Lias: the lowest clayey beds of the Middle Lias with *Ammonites margaritatus*, have thus been often included with the Lower Lias.¶

### *Wigston and Market Harborough.*

North and north-east of Rugby, from near Lutterworth to Wigston Magna, the boundary of the Lower Lias with the beds beneath "is extremely uncertain, on account of the great thickness of Drift which obscures the underlying strata."**

The junction of Lower Lias and Rhætic Beds has been exposed in the large brick-pit at Glen Parva to the south-east of Wigston.

* De Rance, Rep. Brit. Assoc. for 1881, p. 313.

† Rep. Rugby School Nat. Hist. Soc. for 1877, p. 46.

‡ For account of Kilsby Tunnel, which is 1¼ miles long, see Smiles' Life of Stephenson, chap. xiii.

§ T. B. Oldham, Report Rugby School Nat. Hist. Soc. for 1878, p. 54; 1879, pp. 28, 54; 1880, p. 48.

|| Journ. Northamptonsh. Nat. Hist. Soc., vol. vi. p. 208.

¶ See W. T. Aveline and R. Trench, Geology of part of Northamptonshire (Mem. Geol. Survey, Sheet 53 S.E.), p. 4.

** H. H. Howell, in Geology of part of Leicestershire (Mem. Geol. Survey, Sheet 63 S.E.), p. 4.

The bottom beds of the Lower Lias consist of blue-hearted limestones, from 1 foot 6 inches to 9 feet thick. The lowest bands, showing wavy banding and white earthy coating, contain much pyrites, and are considered by Mr. Montagu Browne to represent the "Four-foot bed" of Barrow-on-Soar. *Lima gigantea* occurs, and Mr. H. E. Quilter records also *Ammonites planorbis*, *Cidaris Edwardsi* and other fossils.*

Beds belonging to the zone of *Am. Bucklandi* have been quarried between Wigston Magna and Kilby, and large specimens of *Lima gigantea* have been obtained. Clayey beds and pyritic shales with nodules of limestone, belonging partly to the same zone, and partly to that of *A. semicostatus*, have been opened up in brickyards near Glen Magna and Fleckney.† At Fleckney *Ammonites sauzeanus* and other fossils have been found.

The overlying clays have been worked for brick-making, between Bruntingthorpe and Shearsby, at Kibworth Harcourt, Husbands Bosworth, Market Harborough, Little Bowden, Neville Holt, and Medbourn.

Shelly limestone-bands are occasionally met with in the clays, bands that are of a similar character to the Banbury Marble. One of these bands at Husbands Bosworth yielded *Belemnites*, *Cardinia*, *Gryphæa*, *Lima*, and *Pecten*; but the specimens were not good enough for specific identification.

Prof. Judd has also described bands of like character that were exposed at Staunton Wyville. They yielded *Cardinia attenuata* and *C. hybrida*, and many other shells, including *Belemnites clavatus*, *Hippopodium ponderosum*, *Gryphæa obliquata*, *Littorina imbricata*, *Pentacrinus*, &c. He remarks that these bands of limestone are sufficient to produce, by their greater relative hardness and power of resisting denudation, a well-marked feature wherever the country is sufficiently free from Drift. Thus the ridge on which the village of Thorpe Langton is built, owes its existence to the presence of limestone-bands of the zone of *Ammonites Jamesoni*. A deep ditch south of the village afforded an admirable exposure of these beds in the year 1867, and yielded *Ammonites Valdani*, *Belemnites elongatus*, *Plicatula spinosa*, *Pecten æquivalvis*, *Modiola*, *Ostrea*, and *Pentacrinus* (very abundant).‡

Prof. Judd mentions that the clays in the Neville-Holt brickyard, are dark blue and pyritous, with a few septaria and ferruginous nodules; they yielded *Ammonites capricornus*, *A. fimbriatus*, and *Nucula*.

At Little Bowden brickyard, beds of grey micaceous shale and blue clay have been opened up to a depth of 25 feet, beneath Middle Lias shales. These lower beds belong to the zone of *A. capricornus*.

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* Rep. Leicester Lit. and Phil. Soc. 1885, p. 120; see also Geol. Mag. 1884, p. 415.

† Quilter, Geol. Mag. 1886, p. 60; Midland Nat., vol. iv. p. 265.

‡ Geology of Rutland (Mem. Geol. Survey, Sheet 64), pp. 62, 63.

The following fossils occur :—

| | |
|---|---|
| Ammonites capricornus. | Modiola scalprum. |
| Belemnites clavatus. | —— hillana. |
| Amberleya imbricata. | Plicatula spinosa. |
| Cardita multicostata. | Pentacrinus basaltiformis. |
| Inoceramus ventricosus. | Lignite (partially converted into jet) |
| Leda. | |
| Pecten. | |

The above list includes the species obtained by Prof. Judd and those subsequently collected by Mr. Beeby Thompson and myself.

At Cranhoe brickyard (also described by Prof. Judd) we have an exposure of light-blue stratified clays, with layers of concentric balls of ironstone which fall to pieces on exposure to the air. These nodules contain numerous but imperfectly preserved fossils; the species collected were as follows :—

| | |
|---|---|
| Ammonites Henleyi. | Leda complanata. |
| Belemnites. | Lima pectinoides. |
| Avicula inæquivalvis. | Pecten lunularis. |
| Cardium truncatum. | —— æquivalvis. |
| Cucullæa. | Pentacrinus. |
| Inoceramus ventricosus. | |

The beds here, as noted by Prof. Judd, are near the junction of Middle and Lower Lias; possibly portions of the Middle Lias are represented.*

*Barrow-on-Soar and Melton Mowbray.*

The lowest beds of the Lower Lias near Leicester, consist of beds of banded and fissile argillaceous limestone, alternating with shaly clay; beds which resemble the Insect Limestones in the Lower Lias of Wilmcote and other places.† They also yield remains of Saurians, Fishes and Crustaceans, including *Ichthyosaurus communis, I. intermedius, I. tenuirostris, Plesiosaurus macrocephalus, Belonorhynchus acutus, Oxygnathus Egertoni, Dapedius dorsalis, Eugnathus serrulatus, Pholidophorus Hastingsiæ P. Stricklandi,* and *Eryon barrovensis.* From Barrow-on-Soar there was obtained a specimen of *Ichthyosaurus* with traces of the skin or dermal covering.‡ Among other fossils there are found *Ammonites planorbis, A. Johnstoni, Nautilus striatus, Gryphæa arcuata, Lima gigantea,* and *Rhynchonella calcicosta.* A fine Neuropterous Insect, named *Palæotermes Ellisii,* by Dr. H. Woodward has lately been found in the same strata by Mr. Montagu Browne; and in this specimen the wings are clouded with spots of colour.§

The thickness of the beds is from 30 to 40 feet. These lower beds have been noticed by Prof. Judd in railway-cuttings at Sysonby and Kirby Bellars, and by Mr. Strangways in

* Geology of Rutland, &c., pp. 62, 63.

† Brodie, Proc. Cotteswold Club, vol. ii. p. 139; W. J. Harrison, Sketch of the Geology of Leicestershire, &c., 1877, p. 37; M. Browne, Vertebrate Animals of Leicester and Rutland, 1889, pp. 173, &c.

‡ Buckland, Bridgewater Treatise, vol. ii., Plate 10; W. Davies, Geol. Mag., 1864 p. 248. See also Moore, Proc. Somerset Arch. Soc., vol. xiii. p. 179.

§ Geol. Mag. 1892, p. 193.

the cutting near Rotherby, north-east of Brooksby railway-station.

The principal sections are those in the quarries near Barrow-on-Soar, where the beds shown are as follows:—

| | | Ft. In. | Ft. In. |
|---|---|---|---|
| Lower Lias. Zones of *Ammonites angulatus* and *A. planorbis*. | Blue and brown clay and pyritic shale, with *Ammonites catenatus* | 5 0 to | 15 0 |
| | Thin layer of stone. *Lima gigantea*, *Gryphæa arcuata*; Grey and blue shaly clay | | 15 0 |
| | Limestone "Roof Bed," known also as Rammell or Rummels, with *Am. planorbis* and *Lima gigantea* | | 1 0 |
| | Shale | | 4 0 |
| | Six or seven even "floors" of limestone and clay | | 10 0 |
| | Shale | | 7 0 |
| | Limestone "White Hurls" | | 1 0 |

A few more "floors" are worked in places, sometimes in the open and sometimes by shafts and drifts carried beneath the Roof Bed. The depth from the Rammell to the White Stone (top of Rhætic Beds) is said to be 29 feet, and the thickness of the stone-beds that are worked is from 21 to 25 feet, including shales.

Some of the bands have been employed for paving and other purposes, but much of the stone is very shaly and after exposure it flakes up. It is mainly worked for the Blue Lias Lime and Cement, manufactured by John Ellis and Company.

The beds shown belong mostly to the zone of *Ammonites planorbis*, but the top clays and shales, which in places attain a thickness of about 80 feet, have been designated by Mr. Quilter the zone or sub-zone of *Ammonites catenatus.** This Ammonite is locally found in some abundance; it was however regarded by Prof. Judd† as a variety of *A. angulatus*, and is no doubt an intermediate form, sufficiently pronounced however to be worthy of local distinction. Mr. Quilter regards the form as intermediate between *A. planorbis* and *A. angulatus.*

*A. catenatus* is recorded by Mr. J. D. Paul‡ from beds near Scraptoft and Thurnby, and it has been found with *A. Johnstoni* at the Spinney Hills, Leicester.

Beds belonging to the zone of *A. angulatus* have been observed near Sileby by Mr. Quilter, and also in the railway-cutting on the Uppingham road, near Leicester.

A boring near Evington proved 186 feet of Lower Lias, including the beds from the base up to the zone of *A. Bucklandi.*§

At Crown Hill, north-west of Evington, nearly 50 feet of limestones and clays belonging to the zone of *A. Bucklandi* have been opened up. Mr. Quilter records *A. Charmassei* and other fossils from this locality.||

In an easterly direction the beds are represented mainly by blue clays, with numerous scattered specimens of *Gryphæa*

* Geol. Mag. 1886, pp. 59, 64.
† Geol. Rutland, p. 59.
‡ Trans. Leicester Lit. and Phil. Soc., ser. 2, Part I., p. 23.
§ J. D. Paul, *Ibid.*, 1883–4, p. 83.
|| Report Leicester Lit. & Phil. Soc. for 1883, p. 52.

*arcuata*, &c. Beds of this nature, noted by Prof. Judd, were reached in a deep well in Stapleford Park.*

Blue pyritic clays with occasional bands of limestone, yielding *Ammonites semicostatus*, &c. were opened up in cuttings near Thurnby, and Ingersby or Scraptoft tunnel, east of Leicester.†

Still higher beds of pyritic shale with nodules of limestone, bands of shelly limestone, and ferruginous concretions, belonging to the zone of *A. oxynotus* were exposed by the tunnel between Grimston and Old Dalby, and in a brickyard between Houghton-on-the-Hill and Billesdon.‡

At the potteries at Loseby and in the railway-cuttings near Loseby station, clays and shales with septaria and nodules of ironstone were exposed to a depth of about 25 feet. Towards the middle of the section at the potteries, there was a layer of grey sandy rock. The following fossils were obtained by Prof. Judd:—

| | |
|---|---|
| Saurian vertebræ. | Cardinia. |
| Ammonites armatus, abundant. | Gryphæa cymbium. |
| —— gagateus (Coynarti). | —— obliquata. |
| —— Loscombei, sometimes very large, and the specimens covered with *Ostrea*, *Serpula*, &c. | Hippopodium ponderosum, large rugose variety. |
| Nautilus truncatus. | Lima Hermanni. |
| Belemnites acutus. | Modiola scalprum. |
| Avicula. | Arcomya elongata. |
| | Pholadomya ambigua. |
| | Pentacrinus. |

The beds were grouped by Prof. Judd in the zone of *A. armatus*.§ The occurrence of *A. Loscombei* is however suggestive of higher beds; and Mr. Strangways is of opinion that they include beds belonging to the zone of *A. capricornus*.

Beds belonging to the zones of *Ammonites armatus*, *A. Jamesoni*, and *A. Ibex* have been noted in the railway-cuttings near Freeby and Saxby, and again near Little and Great Dalby. They consist of sandy clay and pyritous shales, with septaria, ferruginous nodules, and occasionally thin bands of impure limestone, and pieces of jet. Beds of this character were shown in a cutting of the Bourn and Saxby railway, east of Saxby, where they were apparently faulted against the Marlstone.

Specimens indicating the zones of *A. Jamesoni* and *A. capricornus* were obtained by Prof. Judd from openings in the Lower Lias clays of Stapleford Park: he enumerates the following:—

| | |
|---|---|
| Ammonites brevispina, rare. | Trochus. |
| —— capricornus, rare. | Cypricardia cucullata. |
| —— Jamesoni. | Gryphæa cymbium. |
| —— latæcosta, abundant. | Limea acuticosta. |
| —— normanianus, rare. | Lima Hermanni. |
| —— trivialis. | Plicatula spinosa. |
| Belemnites clavatus. | Unicardium cardioides. |
| —— elegans. | |

* Judd, Geol. Rutland, p. 59.
† J. D. Paul, Rep. Leicester Lit. & Phil. Soc. for 1883, p. 50.
‡ Quilter, Geol. Mag. 1886, p. 60.
§ Geol. Rutland, p. 61.

*Ammonites Jamesoni* and *Hippopodium ponderosum* were obtained at Great Dalby, by Prof. Judd,* and from Little Dalby he obtained *A. Maugenesti*, *Plicatula spinosa*, and *Montlivaltia rugosa*, forms which recall the beds at Fenny Compton. Fine specimens of *A. armatus* were also obtained at Little Dalby.

As remarked by Professor Judd, the highest beds of the Lower Lias consist of dark blue clays, with much pyrites and many septaria, the latter acquiring a red colour and concentric structure by weathering, and frequently containing thin laminæ of Specular Iron. These beds abound with specimens of *Ammonites capricornus*, and also contain, but more rarely, *Pentacrinus robustus* and some other fossils. They are exposed in the railway-cutting at Galley Hill, near Whissendine.*

*Barnstone and the Vale of Belvoir.*

North-east of Leicester the Lower Lias spreads over a considerable tract of country, an undulating drift-covered district known as the Wolds, on which are situated the villages of Walton-on-the-Wolds, Old Dalby-on-the-Wolds, Wimeswold, and Stanton-on-the-Wolds.

Limestones have been quarried for lime-burning, &c., north of Hoton, on the Normanton and Stanford Hills, between Normanton-upon-Soar and Rempstone, at Cortlingstock, East Leake Hills, near Widmerpool, Kinoulton, Owthorpe, and Cropwell Bishop. The beds at Hoton are much like those of Barrow-on-Soar, and similar organic remains (Saurians, Fishes, and Crustaceans) have been found there and at Cortlingstock.†

A deep boring made at Owthorpe, penetrated the basement-beds of the Lower Lias;‡ a well sunk at the G.N. and L. & N.W. Railway-station at Melton Mowbray, proved a thickness of 230 feet of Lower Lias, beneath a covering of Drift 38 feet thick; and a boring at Scalford Road, near Melton Mowbray, proved 212 feet of Lower Lias (clay with thin bands of limestone), overlaid by 149 feet of Drift.§ (See p. 315.)

The lowest beds of the Lias were exposed in the railway-cutting near Barnstone, where the junction with the Rhætic Beds was noted by Mr. E. Wilson as follows:—‖

| | | | | Ft. | In. |
|---|---|---|---|---|---|
| Lower Lias. Zone of *Am. planorbis.* | | Thin-bedded blue limestones and brown clays, with *Ammonites planorbis*, *Pleuromya costata*, *Ostrea liassica*, and *Modiola minima* - - - | about | 10 | 0 |
| Rhætic Beds | White Lias Series | Compact concretionary bed of limestone - | | 0 3 to 0 | 7 |
| | | Earthy shales with nodules of limestone. | | | |

* Geol. Rutland, pp. 60, 61.

† See Horizontal Section, Geol. Survey, Sheet 48, and Explanation by H. H. Howell; and Jukes, in Potter's History of Charnwood Forest, Appendix, p. 4.

‡ E. Wilson, Midland Nat., vol. vi. p. 198, and Jukes-Browne, Geol. S.W. Lincolnshire, p. 150.

§ De Rance, Rep. Brit. Assoc. for 1883, p. 153.

‖ Quart. Journ. Geol. Soc., vol. xxxviii. p. 453; Jukes-Browne, Geol. S.W. Lincolnshire, p. 19.

The compact bed of limestone was included in the Lower Lias by Mr. Wilson, but it is probably equivalent to a band, of similar character and position at Coddington, which I regard as the top of the Rhætic Beds.*

At the Lime-works at Barnstone the following section was shown:—

| | | Ft. | In. |
|---|---|---|---|
| | Contorted clayey soil and drift - - - - | 2 | 0 |
| Lower Lias Zone of *Am. planorbis.* | Pale argillaceous limestones. Two Skerries, and clay - | 2 | 0 |
| | Racy clay - - - - - - - | 2 | 4 |
| | Two or three beds of limestone. First and Second Urrs, thick and thin beds used for paving floors - | 1 | 8 |
| | Grey shale - - - - - - - | 2 | 6 |
| | Best stone. Nine-inch bed, pale and banded earthy limestone - - - - - - - | 0 | 9 |
| | Shale - - - - - - - - | 1 | 1 |
| | Two or three beds of limestone. Rummels - - | 1 | 4 |
| | Shale - - - - - - - - | 1 | 7 |
| | Limestones. Eighteen-inch bed. top and bottom, wavy-banded and pyritic limestone (like bed at Glen Parva) - - - - - - - - | 1 | 6 |
| | Shale - - - - - - - - | 1 | 6 |
| | Grey argillaceous limestone. Bottom Floor. (Water) | 0 | 8 |

Shelly layers occur in the shales, and there are obscure Bivalves (*Pullastra ?*), small *Inoceramus ?*, *Ostrea liassica*, Spines of Echini, and remains of *Plesiosaurus* and *Ichthyosaurus*.

Northwards, the limestones have been worked at Granby, East Cotham Hill, near Long Bennington, and Coddington. *Ammonites planorbis*, *Cardinia*, &c. have been met with at Granby and Cotham; and species of *Montlivaltia* at Balderton.†

The total thickness of the basement-beds of the Lower Lias (zone of *A. planorbis*) is about 30 feet.

According to Mr. Jukes-Browne, the zones of *Ammonites angulatus* and *A. Bucklandi* consist of dark blue clays with occasional bands of septaria and thin limestone. The fossils, which are sometimes pyritic, include *Ammonites*, *Nautilus*, *Gryphæa arcuata*, *Lima gigantea*, &c. The beds are seldom exposed, but they have been opened up in brickyards near Bottesford, and in other places near Redmile;‡ and probably also in Kinoulton brickyard to the south-west.

The zone of *Ammonites semicostatus* is represented partly by a band of ferruginous limestone and ironstone, containing *Ammonites semicostatus*, *Cardinia gigantea*, *C. Listeri*, *Gryphæa arcuata*, and other fossils. As remarked by Prof. Judd, the bed makes a conspicuous feature in the Vale of Belvoir, and exhibits mineralogical characters, which have caused it to be mistaken for the Rock-bed of the Marlstone. (See Fig. 53.)

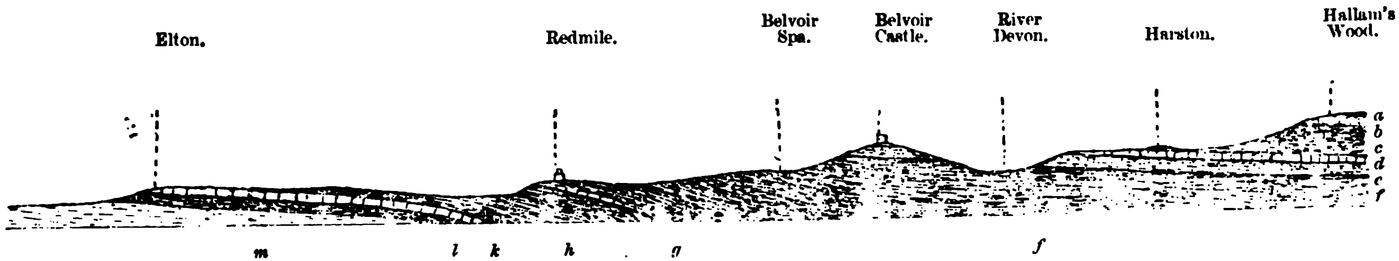
* Geol. Mag. 1874, p. 480.

† See also Jukes-Browne, Geol. S.W. Lincolnshire, (Mem. Geol. Survey, Sheet 70), p. 24.

‡ Geol. S.W. Lincolnshire, pp. 28, 29. See also Fig. 1, p. 10.

FIG. 53.

*Diagrammatic Section across the Vale of Belvoir.* (A. J. Jukes-Browne.)




*a.* Lincolnshire Limestone.
*b.* Northampton Sands.
*c.* Upper Lias Clay.
*d.* Marlstone Rock-bed.
*e.* Middle Lias Sands and Clays.
*f.* Lower Lias Clays.
*g.* Ferruginous rock of the Zone of *Ammonites semicostatus.*
*h.* Lower Lias Clays, with Limestones at base.
*k.* Rhætic Beds.
*l.* Red and green Marls with gypsum (Keuper).

The band has been traced from Harby northwards by Redmile and Foston, but it nowhere in this neighbourhood attains a thickness of more than 5 feet, although it comprises two layers parted in places by a bed of clay 2 feet thick.* A well-boring at Allington Hall, N.W. of Grantham, was carried to a depth of 181 feet in Lower Lias, below these hard bands.

Above the ironstone-band there are dark blue clays with bands of stone, representing the zone of *Ammonites oxynotus*; and sandy clays and thin limestones, representing that of *A. armatus*. These beds were exposed in a brickyard south-west of Broughton-on-Brant; from the beds here *Ammonites raricostatus* has been obtained.

Prof. Judd has recorded the following fossils from the hard ferruginous beds (zone of *A. semicostatus*), in the vale of Belvoir† :—

| | |
|---|---|
| Ammonites semicostatus. | Cardium. |
| Belemnites acutus. | Gryphæa arcuata. |
| Cerithium ligaturale. | Lima gigantea. |
| —— subfistulosum. | —— pectinoides. |
| Pleurotomaria precatoria. | —— punctata. |
| Cryptænia expansa. | Pecten æquivalvis. |
| Amberleya imbricata. | —— lunularis. |
| Astarte. | —— textorius. |
| Cardinia copides. | Pleuromya costata. |
| —— gigantea. | Unicardium cardioides. |
| —— hybrida. | Ditrupa capitata. |
| —— Listeri. | Rhynchonella variabilis. |
| —— ovalis. | |

At Broughton Mills, beds considered to belong to the zone of *Ammonites Jamesoni*, have been worked for brick-making, but as Mr. Jukes-Browne remarks "fossils are scanty and ill-preserved," and no distinctive species are recorded.

A cutting at the foot of the tram-line belonging to the Eastwell Iron-works, showed bluish-grey shaly clays with small nodules of ironstone and cement-stone, and from these beds Mr. W. A. E. Ussher and myself obtained the following species, which were identified by Mr. Sharman‡ :—

| | |
|---|---|
| Ammonites brevispina (fragments abundant). | Plicatula spinosa. |
| Belemnites (abundant). | Unicardium cardioides. |
| Avicula. | Rhynchonella. |
| Pecten lunularis. | Pentacrinus. |

*Ammonites capricornus* was obtained from the clays and ironstone-nodules, exposed in the railway-cuttings between Long Clawson and Harby, and at Barkston junction. The brickyard north-east of Woolsthorpe showed clays with ironstone concretions and septaria; beds probably near the junction of the zones of *A. Jamesoni* and *A. capricornus*.

The total thickness of the Lower Lias, as proved in a well-boring at Spittlegate, Grantham, may be estimated at about 700 feet.§

* Geol. S. W. Lincolnshire, pp. 29-31.
† Geol. Rutland, p. 42.
‡ Geol. S.W. Lincolnshire, p. 32.
§ *Ibid.*, p. 143.

Details were recorded by Mr. W. H. Holloway, who calculated the thickness of the several zones: these may be summarized as follows:—

| | Feet. |
|---|---|
| *A. capricornus* to *A. oxynotus*:—Chiefly clays with septaria and occasional sandy beds - - - - - - | 470 |
| *A. semicostatus* to *A. planorbis*:—Alternations of limestone and clay - - - - - - - - - | 230 |

*Lincoln.*

Near Lincoln the Lower Lias occupies a broad belt of flat country that affords few sections: the minor features in the area being in many cases due to coverings of Drift.

The basement-beds belonging to the zone of *Ammonites planorbis*, are represented by dark clays with bands of grey earthy and shelly limestone, but as a rule there appears no great mass of limestones either in this division or higher up in the Lower Lias.

East of Collingham railway-station there was a quarry and lime-kiln, now abandoned, and the section showed in 1889, about 4 feet of clay, and loose blocks of grey earthy and banded lime-limestone, like the Insect-beds of Warwickshire. At this locality Mr. W. H. Dalton collected *Ammonites planorbis, Avicula inæquivalvis, A. papyria, Lima gigantea, Ostrea liassica,* &c.

The boring at South Scarle (Collingham) proved about 29 feet of Lower Lias clay and limestone.* The limestones were exposed in the railway-cutting south-east of Torksey, and the beds have been extensively quarried there for local building-purposes.†

Beds of clay and shale with bands of limestone, represent the zones of *Ammonites angulatus* and *A. Bucklandi.* They have been noticed near Eagle, in cuttings south of Marton railway-station, and near Stow, in the brickyard south of Heapham, and near Great Corringham. *Ammonites Bucklandi, Gryphæa arcuata, Lima gigantea, Pentacrinus,* &c. occur.

More interest attaches to a band of ferruginous and calcareous sandstone, with subordinate clays, that represents the zone of *Ammonites semicostatus.* It has been traced, by Messrs. Ussher and Dalton, at intervals northwards from the area previously noted in the Vale of Belvoir, but the outcrop can only be detected in places. North of Bassingham Church the following fossils were obtained‡:—

| | |
|---|---|
| Amberleya gaudryana. | Pinna. |
| Chemnitzia (?) liassica. | Pholadomya ambigua. |
| Gryphæa arcuata. | Unicardium cardioides. |
| Lima. | Rhynchonella. |
| Ostrea. | Spiriferina Walcotti. |
| Pecten Thiollieri. | |

A somewhat similar assemblage was obtained north of Eagle, although the beds there appear to be on a rather lower horizon.

* E. Wilson, Quart. Journ. Geol. Soc., vol. xxxv. p. 812. See also W. H. Dalton, Geol. Mag. 1887, p. 48; Geol. Lincoln, p. 194.

† Geology of the country around Lincoln, p. 17.

‡ Geology of Lincoln, pp. 19, 20.

Mr. Dalton mentions that calcareous sandstone was at one time worked for road-metal at Haddington and Thorpe-on-the-Hill, where the beds form a marked feature; but their further extension northwards is very doubtful. Beds of sandy Lias occur at Broxholme, but they are considered by Mr. Dalton to be on a higher horizon. Ferruginous rubbly limestones occur also at Stow and Willingham, and these beds are considered by Mr. Ussher to belong most likely to the zone of *Ammonites semicostatus*. There are however no indications in this region of the valuable ironstone met with on this horizon still further north.

A brickyard south-east of Bassingham showed the following section, which was noted by Mr. Dalton:—*

| | | Ft. | In. |
|---|---|---|---|
| | Soil and Drift clay | 1 | 6 |
| Lower Lias. Zone of *Ammonites armatus.* | Clay | 1 | 6 |
| | Ferruginous sandstone | 2 | 0 |
| | Fossiliferous calcareous rock | 2 | 0 |
| | Blue clay | 6 | 0 |

The following fossils were obtained here by Mr. Rhodes:—

Ammonites subplanicosta.
Avicula inæquivalvis.
Cardinia Listeri.
Gryphæa cymbium.
Modiola scalprum.
Pecten lunularis.
Pholadomya ambigua.
Pinna Hartmanni.
Pleuromya.
Pentacrinus.

The beds are considered to belong to the zone of *Ammonites armatus*, which in the area to the south, near Broughton-on-Brant, and in some other localities, includes beds of a sandy nature.

Ironstone was noticed in these beds east of Broxholme, suggesting that the formation of this ore occurs at different horizons, according to the presence of porous layers here and there in the Lias clays. This band appears to range northward by Broxholme, and Thorpe-in-the-Fallows to Coates.

The uppermost beds of the Lower Lias have been well exposed in the brickyard north of Waddington railway-station. There about 30 feet of clay has been dug, the uppermost 6 feet of it being regarded by Mr. Ussher as belonging to the base of the Middle Lias; below, the beds consist of grey clay with ferruginous septaria and cement-stones. The following fossils were obtained:—†

Ammonites capricornus.
—— striatus.
—— subplanicosta.
Belemnites clavatus.
Actæonina.
Amberleya imbricata.
Cardium truncatum.
Gervillia lævis.
Goniomya.
Leda galathea?
Modiola scalprum.
Ostrea.
Pecten æquivalvis.
—— Thiollieri?
Pholadomya ambigua.
Pleuromya costata.
Plicatula spinosa.
Unicardium.
Rhynchonella variabilis.

* Geology of Lincoln, p. 21.
† *Ibid.*, p. 22.

About a mile and a quarter further north, the Bracebridge Brick Company's pit showed, at the base of the Middle Lias clays, about 10 feet of clay yielding *Ammonites capricornus* and *A. striatus*. A trial-boring at Bracebridge was carried to a depth of 320 feet without reaching the base of the Lower Lias; saline water was then obtained. (See p. 322.)

In this area, as elsewhere, the boundary between Middle and Lower Lias is very indefinite, as the beds lithologically cannot be distinguished.

### *Frodingham and North Lincolnshire*

The basement-beds of the Lias (zone of *Ammonites planorbis*) in North Lincolnshire, comprise clays with bands of limestone, attaining a thickness of 20 feet or more. Remains of *Ichthyosaurus*, *Amberleya Chapuisi*, *Lima gigantea*, *Modiola minima*, *Ostrea liassica*, *Pleuromya crowcombeia*, &c. have been obtained. The beds have been exposed at Scotterwood, west of Scotter, near Messingham Mill, and in the low cliff north of Burton-upon-Stather. The junction with the Rhætic Beds is not to be seen in section: these beds consist in the upper part of marly shales, with on top a band of compact limestone.

The zones of *Ammonites angulatus* and *A. Bucklandi* are represented by grey and blue compact and nodular limestones, with thicker masses of clay and shale, that form in places a well-marked escarpment. West of Frodingham station there is a fine section of the beds, which there attain a thickness estimated by Mr. Ussher at 170 feet. Iron-shot grains occur in some of the upper beds, near the junction with the overlying zone. *Gryphæa arcuata* is very abundant. *Ammonites Bucklandi*, *A. Conybearei*, *Lima gigantea*, *L. Hermanni*, *Cardinia Listeri*, *Spiriferina Walcotti*, and other fossils have been obtained.*

The beds have been quarried to the south, by the road west of Brumby, where they have been opened to a depth of 20 feet. Peculiar cup-shaped nodules, or nodules resembling the mouth of a funnel, have been observed in these beds in several places by Mr. Ussher.

The most northerly exposure of these strata, is in a quarry opposite Whitton pier, where the beds of brown and grey clay and limestone were exposed to a depth of 18 feet, beneath a capping of gravel. *Gryphæa arcuata* and Pentacrinites are abundant. Many fossils from this locality were noted 160 years ago by J. Woodward.†

The most important division of the Lower Lias in this region is the Frodingham Ironstone, a group of ferruginous and fossiliferous limestones, which belong to the zone of *Ammonites*

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* J. E. Cross, Quart. Journ. Geol. Soc., vol. xxxi.; and Ussher, Geology of North Lincolnshire, &c., pp. 13, &c.

† Nat. Hist. Fossils of England, vol. i., Part 2, pp. 26, 30, 32, &c.

*semicostatus.* The position of these beds was first determined by the Rev. J. E. Cross.

The beds attain a thickness of from 20 to 30 feet, and consist of harder and softer bands of brown ferruginous limestone and calcareous ironstone, with occasional traces of oolitic structure.

The following are among the fossils that have been obtained:—*

| | |
|---|---|
| Ichthyosaurus communis. | Modiola scalprum. |
| Ammonites Conybearei. | Pecten æqualis. |
| —— semicostatus. | —— æquivalvis. |
| Nautilus striatus. | —— demissus. |
| Belemnites acutus. | —— textorius. |
| Pleurotomaria anglica. | Pholadomya ambigua. |
| Cardinia Listeri, var. ovalis. | Spiriferina Walcotti. |
| —— gigantea. | Extracrinus. |
| Gryphæa arcuata. | Serpula. |
| Lima gigantea. | Lignite. |
| —— Hermanni. | |

The more abundant forms are *Gryphæa*, *Cardinia*, *Pecten*, and fragments of *Ammonites semicostatus.*

These beds have been traced northwards to the Humber shore east of Whitton, and southwards to near Northorpe station.

Where uncovered by Drift, the beds are indicated by a reddish soil, and they are exposed in occasional small quarries, near West Halton, Coleby, and Thealby, where the stone is obtained for road-metal.

The beds are of variable character, and consist largely of ferruginous and shelly limestones, brown, grey, and greenish in colour, with layers of ferruginous matter and ironstone. Be ls of a profitable character have been worked some distance on either side of the Trent, Ancholme, and Grimsby railway, near Frodingham station, on Crosby, Scunthorpe, Frodingham, and Brumby Warrens.

To the south of this tract exposures are few; ironstone has been observed here and there, but for the most part the beds consist of rubbly and ferruginous limestone with clay-bands, resembling the unproductive beds of the Frodingham quarries.†

The Frodingham Ironstone is overlaid by a series of blue clays and shales, surmounted by a band of shelly ironstone yielding *Pecten* and other fossils, and known as the Pecten-bed.

Mr. Ussher notes the thickness of the blue clay and shale below the Pecten-bed to be 90 feet south of Appleby station (as proved by borings), and to be about 140 feet south-west of Kirton Lindsey railway-station.

The lower portion of the clay has yielded *Ammonites Birchii*, but its fossils are not sufficiently well-known.

In the upper portion, bands of chert-nodules were noticed by the Rev. J. E. Cross, and among the fossils the following may be mentioned:—

---

* Geology of North Lincolnshire, pp. 21, &c.
† See Ussher, Geol. N. Lincolnshire, pp. 21–31.

| | |
|---|---|
| Ammonites capricornus. | Modiola scalprum. |
| —— Henleyi. | Pecten æquivalvis. |
| —— latæcosta. | —— lunularis. |
| —— Loscombei. | Pholadomya ambigua. |
| —— raricostatus. | Pinna folium. |
| —— Taylori. | Pleuromya costata. |
| Belemnites clavatus. | Plicatula spinosa. |
| —— paxillosus. | Unicardium cardioides. |
| Inoceramus ventricosus. | Spiriferina. |
| Gryphæa cymbium. | Waldheimia numismalis. |
| Hippopodium ponderosum. | Pentacrinus. |
| Lima pectinoides. | |

This assemblage is suggestive of the zones of *A. armatus*, *A. Jamesoni*, and the lower part of that of *A. capricornus*.

Above these clays comes a band of ironstone about 4 feet thick, named by the Rev. J. E. Cross the "*Pecten*-ironstone." This Pecten-bed contains the following fossils :—

| | |
|---|---|
| Ammonites armatus. | Lima antiquata. |
| —— Henleyi. | —— Hermanni. |
| —— striatus. | Modiola scalprum. |
| Belemnites elongatus. | Pecten æquivalvis. |
| Cardinia hybrida. | —— lunularis. |
| —— Listeri. | Pleuromya costata. |
| Cardita multicostata. | Tancredia ovata. |
| Cypricardia intermedia. | Rhynchonella tetrahedra. |
| Gryphæa cymbium. | —— variabilis. |
| —— gigantea. | Terebratula punctata. |

This assemblage (with the exception of *A. armatus*) is essentially one characteristic of the higher stages of the Lower Lias; the presence of forms like *Cypricardia intermedia* recalls beds at Chipping Norton, which belong in part to Lower and in part to Middle Lias. The Pecten-bed has been traced from near Winteringham to the neighbourhood of Kirton Lindsey, but not far southwards of that locality.

Overlying the Pecten-bed there is a series of clays with ferruginous nodules and septaria, over 60 feet in thickness, which appear to contain *Am. capricornus* throughout. No specimens of *A. margaritatus* are known from this division, but it is directly overlaid by the Marlstone Rock, or upper part of the Middle Lias.

These clays were exposed in the railway-cutting south of Santon Warren, where they yielded the following fossils:—*

| | |
|---|---|
| Ammonites capricornus. | Pecten æqualis. |
| Belemnites paxillosus. | Pholadomya ambigua. |
| Avicula inæquivalvis. | Plicatula spinosa. |

Near Cleatham Grange *Hippopodium ponderosum*, *Belemnites tubularis*, &c. have been found.

In the absence of *Ammonites margaritatus*, and looking to the general character of the fauna of these beds, it is best to regard them as belonging to the zone of *Ammonites capricornus*.

It is possible that further researches may show that *Am. margaritatus* occurs in the top beds of this clay-series: the zone being very much attenuated. The Pecten-bed was however taken as the base of the Middle Lias by Mr. Ussher, as it afforded a convenient boundary in mapping the district.

* Ussher, Geol. N. Lincolnshire, p. 42.

### *Needwood Forest.*

The occurrence of "Lower Lias" on the high ground of Needwood Forest was made known during the course of the Geological Survey by J. B. Jukes and Mr. H. H. Howell. The beds then traced out, belong to the series now grouped as Rhætic: the only remnants of Lias being fossils occasionally found in the Drift deposits.

### *Shropshire and Cheshire.*

A tract of Lower Lias occurs in North Shropshire and on the southern borders of Cheshire. The area is largely covered with Drift deposits, to the depth of 80 or 90 feet in places. These Drifts consist mostly of sand with a stony soil, or of clay; but being of little economic value they are not often exposed in pits.

The ground is gently undulating, and it rises from 200 to upwards of 400 feet. One of the highest points is at Prees (383 feet), a little south of the church, where the Middle Lias, there comparatively free from Drift, forms a prominent hill; while at Ash Magna between Ightfield and Whitchurch the elevation is 421 feet.

The occurrence of Lias in this area was ascertained by Murchison in 1834, and about 20 years later the beds were mapped for the Geological Survey by Mr. A. R. C. Selwyn.

The main area occupied by the Lias was pointed out by Murchison, who acknowledged assistance received from the Rev. T. Egerton and the Rev. W. Egerton.* Attention was drawn to the subject by sinkings made in search of coal, in the district between Whitchurch and Market Drayton. The reported "coal shale" proved to be Lias shale, containing lignite. Thus shafts penetrating Lias, were sunk to the depth of 400 feet at Wolliston, 300 feet near Cloverly and Adderley, while on Wolliston Common a shaft was sunk 240 feet and a boring continued to 150 feet more, and numerous fossils were extracted. Among the fossils from the Lower Lias of this district, the following may be mentioned:—

Ammonites angulatus.
—— Bucklandi.
—— Conybearei.
—— planicosta.
—— planorbis.
—— semicostatus.
—— striatus.
Belemnites.
Gasteropods.
Arca.
Avicula cygnipes (Prees and Adderley Brook).
Cardinia Listeri and vars. ovalis and hybrida.
Gryphæa arcuata.
—— cymbium.
—— obliquata.
Lima gigantea.
—— pectinoides.
Modiola minima (Burley Dam).
Ostrea irregularis. ?
Pecten (Burley Dam).
Pleuromya costata.
Spiriferina Walcotti ?
Cidaris.
Pentacrinus scalaris.
Lignite.

* Proc. Geol. Soc., vol. ii., pp. 114, 115; and Silurian System, pp. 23, 24, 25, and Plate xxix., figs. 2 and 3. See also G. H. Morton, Proc. Liverpool Geol. Soc., 1863-64, p. 2; and R. A. Eskrigge, Trans. Manchester Geol. Soc., vol. iv. p. 318.

*Gryphæa arcuata* and *Cardinia Listeri* (var. *ovalis* and *hybrida*) are abundant in the Drift near Prees.

Murchison states that "some of the sinkings [for coal] produced small pieces of jet or lignite like that of Whitby; others nearer the escarpment went through the Lias, and reached brine springs in the subjacent red marl."* This was the case in the boring at Adderley, opposite Kent's Rough, after piercing black shale, and at a depth of 300 feet.

Mr. Henry Ikin informed me that a boring for coal was made about ¾ mile S.E. of Prees church, on the low ground at the foot of the Marlstone outlier. The site is in a small plantation, but no traces of the spoil-heaps are now to be seen. Probably the stone brought up was of sufficient value to be removed. Mr. Ikin however had picked up one thin slab of limestone, of Rhætic aspect, which contains *Modiola minima* and some other fossils. This he kindly presented, as well as other specimens from the Middle Lias of Prees, to the Museum at Jermyn Street.

Murchison remarked in reference to the Lias that "The western boundary is ill defined, owing to the low and featureless form of the ground and its being covered by vast accumulations of gravel, sand, and peat-bog. It is therefore possible that the Lias may extend in this direction to some distance; but even assuming that it does not, and limiting the boundary by a line passing from Wem and Edstaston to Burley Dam, east of Combermere, places where the formation has been detected, we find this bowl has a length of about 10, and a breadth of three to four and a half miles." He adds that "At Moreton Wood south of Cloverly [near Moreton Say] the Lias dips westerly, thus indicating that it is there near the eastern side of the basin; whilst at Audlem and Burley Dam, along the north-eastern and northern boundary, the strata dip south-west and south, at angles varying from 5° to 7°." He further mentions that "The Lower Lias consists entirely of finely laminated shale, as proved by shafts which have been sunk on Wolliston Common. In the vicinity of Burley Dam, some of the beds are so hard as to have induced Lord Combermere to quarry them for slating purposes, and others at the same locality being slightly bituminous have very much the mineral aspect of Kimmeridge Coal. At Lightwood Green, the shale was found to contain nodules of ferruginous cement-stone; while at Cloverly, beneath numerous beds of dark marly shale, occurred one thin band of hard white stone with others of a dark colour."†

Mr. Ikin has obtained *Pleuromya costata* from a well 22 feet deep at Wolliston, N.E. of Prees.

Lower Lias was exposed in the banks of the brook (one of the feeders of the river Weaver) that rises north-west of Butterley Heys, south-west of Audlem.

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* Murchison mentions borings for coal at Heathgate, Moreton Wood, Prees Wood, Calver Hall (Calvin Wood), Burley Dam, Marchamley, Cloverly, and Wolliston Commons, &c. Sil. Syst., p. 23.

† Sil. Syst., pp. 22, 23.

In the little plantation (where a dip of 5° S.S.E. was recorded on the Geological Survey Map) I found exposures of grey earthy marls with thin layers and nodules of grey and bluish-grey limestone, resting on darker grey shaly marls to the depth of about 4 feet. They yielded no fossils, and from the fact that traces of red staining occurred in these marls lower down the stream, the evidence favoured their being of Lower Rhætic age. Moreover a little to the east of the track-way between Stairs and Butterley Heys, the banks showed a mass of red clay. Although this might belong to the Drift, being in that case rearranged Triassic clay, yet its presence in connexion with the grey and red-tinged marls before mentioned, favoured the notion of the Rhætic age of the grey marls in the plantation.

Lower still down the stream (near Audlem) there was exposed from 4 to 6 feet of unmistakeable Lower Lias as follows:—

| | | Ft. In. | Ft. In. |
|---|---|---|---|
| Lower Lias | Grey and rusty yellow clay passing down into blue shaly clay with *Cardinia Listeri* and *Lima gigantea* - - - | 4 0 to | 6 0 |
| | Band of limestone with *Lima gigantea* - | 0 2 to | 0 3 |
| | Grey shales in bed of stream, dipping gently towards the N.W. | | |

*Ammonites angulatus* and *Gryphæa arcuata* were found here by the Rev. T. W. Norwood of Wrenbury; and Mr. C. E. De Rance has obtained *Arca* and *Ostrea irregularis?* If we regard the beds seen higher up the stream as Rhætic, there must be a fault a little east of the track-way before mentioned.

North-west of the church at Burley Dam, there is a plantation through which a stream has cut into the Drift, and exposed in its banks, and on its bed, hard greenish marls. They are overlaid by red and variegated marls, evidently Keuper, and I could detect no traces of Rhætic Beds where a dip of 8° S.S.E. is marked on the Geological Survey Map.

Evidence has been obtained for extending the Lias further westwards, and eastwards probably also, while the boundary taken on the north, near Burley Dam, must be brought a little further south. Thus the Rev. T. W. Norwood has discovered traces of Rhætic beds and Lower Lias in the banks of the stream, north-west of Heald, between Frith Farm and Wrenbury Wharf. He obtained *Pleuromya crowcombeia*, and shales with *Cardium rhæticum*.

A specimen of *Ammonites striatus* was procured by Mr. Ikin from Fauls Green east of Prees. In this case the Lias is perhaps faulted against the Keuper Marls, as shown on the Survey Map, although the former formation should extend further east to the fault. Mr. Ikin also obtained a specimen of Lias rock with *Gryphæa obliquata*, *Lima*, and *Belemnites* from the bank of a road-cutting near Marchamley, between Marchamley and Hodnet. I was unable to verify its occurrence *in situ;* the block was probably procured from the Drift.

The evidence obtained in this area, goes to show that we have, resting on the Red Marls and Rhætic Beds, a succession of Lower Lias beds that exhibit similar characters to the beds in Gloucestershire and Worcestershire, and afford evidence of the zones from that of *A. planorbis* to that of *A. Jamesoni* or *A. Henleyi.*

*Cumberland.*

Extending over a considerable tract to the west of Carlisle, there is an outlier of the basement-beds of the Lower Lias.

The area is for the most part a plateau, and this is more marked between Aikton and Great Orton than further east. Geologically speaking it is a somewhat dreary country, for the most part covered with a thick accumulation of earthy Drift gravel; and we have therefore the same difficulty in fixing the limits of the subjacent Lias, as in the larger Drift-covered tract in Shropshire and Cheshire.

The presence of the dark shales of the Lias in this part of Cumberland, has led during the past 250 years to a number of borings in search of coal; but the identification of the Lias, originated with Mr. R. B. Brockbank, who found *Ammonites* and other fossils in the shales exposed in the banks of Thornby Brook, south-east of Aikton. The specimens were sent to E. W. Binney, who in 1859 published an account of the strata; he noticed the presence also of limestones with Lower Lias fossils at Quarry-Gill, near Aikton, where the stone had formerly been excavated.* At Wiggonby a bore-hole had been put down 120 feet into dark shales, and near Great Orton a boring made in 1781, reached blue stone below the Drift, at a depth of 18 feet from the surface, and after passing through "different stone, mostly bluish," to a depth of 228 feet, passed into the New Red rocks.

The evidence has been carefully studied by Mr. T. V. Holmes, who constructed the Geological Survey map of the area; and he discovered a third exposure of dark shale with bands of limestone, in a brook between Great Orton and Flat. The Lower Lias consists of shales with bands of limestone, some of them sandy and micaceous; and it has yielded *Ammonites Johnstoni, Gryphæa arcuata,* and *Ostrea.*

The Ammonite has been found at the three exposures of the Lias, and thus there is no evidence to show that any beds above the zone of *A. planorbis* are preserved in the area.

The question is whether any of the strata passed through in the Orton boring, can be referred to the Rhætic Beds. Mr. Holmes remarks that their existence "in this district is, and is likely to remain, an open question." He has expressed the opinion that the Lias probably rests on the Gypseous Shales west of Great Orton, and on the Kirklinton Sandstone east of that village; the

* Quart. Journ. Geol. Soc., vol. xv. p. 550; see also Sedgwick, Trans. Geol. Soc., ser. 2, vol. iv. p. 383.

Stanwix Marls underlying the Lias only in the neighbourhood of Bellevue. He considered that these three sub-divisions of the New Red Series were all unconformable to each other. He has, however, admitted the *possibility* that the Stanwix Marls, which he groups as Keuper, may overlap the two lower formations (Kirklinton Sandstone and Gypseous Shales), and underlie the Lias throughout the area.*

No evidence of Rhætic Beds is forthcoming from any part of the area, and I searched carefully in the Drift-deposits, to see if any fragments had been preserved in them; but without success. Nevertheless it appears to me most probable that they are represented, when we bear in mind that they are nearly always present in other parts of this country where the Lias rests upon the New Red Series. At any rate the Great Orton Boring gives us a thickness of 210 feet for the Rhætic Beds (if present) and zone of *Ammonites planorbis.*

With regard to the extent of the Lias, Mr. Holmes has marked the boundary a little south of Great Orton, west of Aikton, and north of Kirk Bampton. All the known sections, as he remarks, are between Great Orton and Aikton; but he infers that the Lias comes as near Carlisle as Bellevue, or a little nearer.

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* Quart. Journ. Geol. Soc., vol. xxxvii. pp. 294–297; Proc. Geol. Assoc., vol. vii. pp. 417, &c.; and vol. xi. pp. 243, &c.

# CHAPTER VII.

## MIDDLE LIAS.

### General Description.

The Middle Lias consists in its lower portion of bluish-grey micaceous marls and clays, passing upwards into laminated sands and clays with nodular layers of limestone and calcareous sandstone. These beds, in places, are surmounted by yellow micaceous sands, with indurated masses or "doggers" of calcareous sandstone. The higher portion of the Middle Lias comprises variable layers of stone, to which the name of "Rock Bed" is sometimes applied, but the beds are more usually grouped under the general name of Marlstone.

The term Marlstone was at first employed by William Smith (1815–16), to include not only the Middle Lias "Rock Bed," but the basement limestones of the Upper Lias, argillaceous limestones for which the name Marlstone was especially appropriate. The term now is restricted to the Middle Lias, and is sometimes employed, as Marlstone Series, to embrace the entire formation. The Marlstone proper, or upper portion of the Middle Lias, includes, in places, beds of yellow micaceous sand and sandstone (before noted), but its most characteristic strata are beds of tough iron-shot and earthy limestone that occasionally contain small calcareous nodules. These beds, where unweathered, are blue or greenish-grey in colour, but near the surface they become brown, and being extensively quarried they are then known as the "Brown Rock." These earthy limestones pass on the one hand into calcareous sandstones, and on the other into valuable beds of ironstone. The iron-shot grains that occur in some of the beds, are tiny spheroidal grains of peroxide of iron, that sometimes exhibit oolitic structure; but as noted in reference to beds in the Lower Lias, an iron-shot appearance may be independent of true oolitic concretions.

The Middle Lias is thus on the whole more variable in character than either the Lower or Upper Lias.

The beds of sand that occur above the clays in Dorsetshire and Somersetshire, assist in forming an escarpment in these southern counties, but the sandy beds are less defined in Gloucestershire and Oxfordshire, and are nowhere very prominently exhibited in the country northwards to Lincolnshire. In Yorkshire the lower part of the Middle Lias has been called the "Sandy Series," and the upper part the "Ironstone Series"; so that the general characters of the subdivisions are there maintained.

The Rock Bed, which is but feebly represented on the Dorsetshire coast, is nowhere well developed in the area near Beaminster. Further north it attains some importance at Ilminster and South Petherton, but eastwards, near Yeovil and South Cadbury, it is

but a thin band. Some of the layers at the eastern end of the Mendip range, are conglomeratic, and contain pebbles of Carboniferous Limestone. Thence to Bath the Rock Bed is probably represented by soft beds. In Gloucestershire it is well developed near Wotton-under-Edge and Dursley, but near Stroud it is insignificant as a Rock Bed. Eastwards at Bloxham, Adderbury, and King's Sutton near Banbury, it becomes a well-marked formation, and has been extensively worked as an iron-ore; while further north at Edge Hill it furnishes an important building-stone. Near Market Harborough the stone-beds are again feebly represented, but near Melton Mowbray and onwards to Grantham there are further valuable beds of ironstone. Northwards in Lincolnshire the stone-beds are but occasionally developed to any prominent degree.

The Middle Lias has been divided into two zones, as follows:—

| | |
|---|---|
| *Ammonites spinatus* (Fig. 54) | Marlstone of variable thickness.<br>Micaceous sands with indurated bands. (Local.) |
| *Ammonites margaritatus* (Fig. 55) | Laminated sands and clays with indurated bands.<br>Blue micaceous clays with nodules of limestone. |

*Ammonites margaritatus* is not confined to the lower beds, but some of the finest examples occur in the same beds with *A. spinatus* in many localities. North of Cheltenham, as remarked by Dr. Wright, it is difficult to separate the beds belonging to the zones of *Ammonites spinatus* and *A. margaritatus.**

Fossils are usually to be met with in abundance in the Marlstone. The sands as a rule are not fossiliferous. The laminated beds are rarely exposed inland, but the blue clays are used for brick-making, and usually yield small specimens or fragments of *A. margaritatus.*

The thin bed of Marlstone exhibited on the Dorset coast includes a layer which has yielded, among other fossils, a great many Gasteropoda, and this has been termed the *Pleurotomaria*-bed; but the Rock Bed there represents only a portion of the Marlstone of other localities.

North-east of Banbury there is a remarkably rich bed on top of the Marlstone; it yields in abundance *Ammonites acutus*, and has been termed the zone of that fossil. The term "Transition-bed" has also been applied, for in some respects it presents evidences in its fauna of a passage between the Middle and Upper Lias. No doubt it is approximately on the same horizon as the *Pleurotomaria*-bed of Dorsetshire, as pointed out by Mr. E. A. Walford and Mr. Beeby Thompson; and they have suggested, with good reason, that it may represent the zone of *Ammonites annulatus*, which forms a distinct horizon at the base of the Upper Lias of Yorkshire.

* Wright, Lias Ammonites (Palæontograph. Soc.), p. 94.

The total thickness of the Middle Lias in Dorsetshire is 345 feet; in Somersetshire, from a few feet to 230 feet; in Gloucestershire, it is from 60 to about 280 feet; in Northamptonshire (Kettering) and in Lincolnshire (Grantham) 150 feet.

Throughout the Jurassic Series there is probably no more definite plane of separation than that between the Middle and Upper Lias, for the so-called Transition-bed is so thin that it nowhere interferes with the boundary-line. The basement-beds of the Upper Lias are pale, earthy, and compact limestones, that occur in a more or less interrupted or nodular form, in clays, and they yield *Ammonites bifrons, A. communis, A. serpentinus* or *A. falcifer,* and other species in fair abundance, although some of them occur sparingly in the Marlstone. Lithologically, palæontologically, and stratigraphically there is rarely any difficulty in deciding the junction, except in a few localities where the Rock Bed of the Middle Lias is not developed.

While the Upper Lias is generally to be distinguished from the Middle Lias, it is a matter of great difficulty to fix a divisional-plane between the Middle and Lower Lias. This arises from the fact that the division has been taken in a series of marls and clays, it is established entirely on palæontological grounds, and authorities differ on the question where it should be taken.

It matters but little where the division is taken under such circumstances, so long as the same approximate stratigraphical and palæontological horizon is adopted. On the Geological Survey Maps the line of demarcation has generally been taken at the base of the zone of *Ammonites margaritatus*—although exceptions occur, inasmuch as near Banbury, the blue clays containing this Ammonite have been included with the Lower Lias. Such inconsistencies are likely to arise when the mapping depends on palæontological evidence, for this evidence is not always forthcoming. Prof. Green in discussing this question, has suggested that it would be better on the Geological Maps to survey simply on lithological grounds—separating the Clays, Sandstones, Ironstones, and Limestones, and "leaving it to the palæontologist to decide to which of the three subdivisions the strata distinguished on the map ought in each locality to be assigned."*

Such a plan undoubtedly would best serve economic purposes, and it might, perhaps, be adopted without neglecting at the same time to indicate the strata that are on the same stratigraphical horizon; for we have seen that the development of limestones in the lower portion of the Lower Lias is subject to much variation, and that by attention to the fossils it is possible to mark approximately the different stages of the formation. In the same way an approximate boundary (for there is no real boundary), can be drawn between Middle and Lower Lias by separating the deposits in which here and there *Ammonites capricornus* and *A. Henleyi* may be found in fair abundance, from those yielding *A. margaritatus.*

* Review of "The Yorkshire Lias," Nature, December 7, 1876, p. 114.

As we know that some species of Ammonites range from Lower to Middle Lias, or from Middle to Upper Lias, it is of course hazardous to state that any one of the zonal species occurs only within certain limits. The evidence, indeed, is opposed to such a supposition, and we are sometimes in great difficulty to decide whether locally a species has a higher range than usual, or whether some of the strata are very much attenuated. This is the case in Lincolnshire where we must either group strata yielding *A. capricornus* in the Middle Lias, or conclude that the zone of *A. margaritatus* is present only in a very attenuated form. At Staithes in Yorkshire, *A. capricornus* (small specimens), and *A. margaritatus* occur together in beds that are grouped as Middle Lias* ; and I have found the two species in the same bed, in the lower part of the Middle Lias of Raasay.

The difficulties in this and other cases arise from the need of fixing some artificial boundary for the purposes of mapping the strata and indexing the fossils; and the only plan to adopt, is to group the beds where *A. capricornus* is prevalent with the Lower Lias, and those yielding *A. margaritatus* with the Middle Lias; while admitting that here and there passage-beds may occur in the midst of which a doubtful boundary must for convenience be drawn. The different groupings adopted by geologists with reference to the lower boundary of the Middle Lias, have been elsewhere stated (see p. 33).

That there was no great break between the Middle and Upper Lias is indicated by the conformity of the strata. But we have a general change from calcareo-arenaceous strata to those of a calcareo-argillaceous type; and there is evidence in the very fossiliferous character of the Marlstone, and the great variety of species locally preserved, of slow and scanty deposition of sediment followed probably in places by an absence of deposition for a time.†

The Marlstone in several localities has yielded forms of an Upper Lias character, species identified by some authorities as *Ammonites annulatus*, *A. communis*, *A. crassus*, *A. Holandrei*, *A. serpentinus*, &c., having been obtained from the Rock Bed. (See p. 245.) At the present day when more attention is paid to minute differences of form, and the species of old authors (unfortunately) are split up more and more into other so-called species or "mutations," great difficulties attend all identifications. It is, however, sufficient for our purpose if we recognize the incoming of Upper Lias forms during the closing stages of the Middle Lias. It may be indeed that the new comers became to a certain extent commingled with the earlier forms, in the still unconsolidated mud of the Middle Lias; but on this point we can only throw out the suggestion, while stating the fact of the preservation of Upper Lias Ammonites in the Marlstone.

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* See Wright, Lias Ammonites, p. 97, and Fox-Strangways, Jurassic Rocks of Yorkshire, p. 76.

† See also Judd, Geol. Rutland, p. 65.

The Fauna of the Middle Lias is not by any means so rich as that of the Lower Lias. Vertebrate remains are but rarely found. Occasional bones of *Ichthyosaurus* and of *Thaumatosaurus* (*Plesiosaurus*) represent the Reptiles; and of Fishes we find only here and there remains of *Hybodus* and *Lepidotus*. Of Mollusca, the Ammonites include *A. acutus*, *A. Engelhardti*, *A. fimbriatus*, *A. margaritatus*, and *A. spinatus*. Forms like *A. Bechei*, *A. capricornus*, *A. Loscombei*, and *A. striatus*, characteristic of the higher beds of the Lower Lias have been recorded, but as will be seen, it is most difficult to draw any satisfactory plane of division between the strata of Lower and Middle Lias. Belemnites are abundant, more especially in the Marlstone, and this division (including the Transition Bed) has yielded a large assemblage of Gasteropoda, belonging to the genera *Actæonina*, *Cerithium*, *Chemnitzia*, *Cryptænia*, *Discohelix*, *Pleurotomaria*, *Solarium*, *Trochus*, and *Turbo*. *Dentalium* also occurs. Of Lamellibranchs we have a large series of genera including *Arca*, *Arcomya*, *Astarte*, *Cardinia*, *Cardium* (*Protocardium*), *Cucullæa*, *Cypricardia*, *Goniomya*, *Gryphæa*, *Hinnites*, *Leda*, *Lima*, *Modiola*, *Nucula*, *Ostrea*, *Pecten*, *Pholadomya*, *Pinna*, *Pleuromya*, *Plicatula*, *Unicardium*, &c. Brachiopoda are especially abundant in the Marlstone, and include *Leptæna* and *Koninckella*, *Rhynchonella*, *Spiriferina*, *Terebratula*, *Waldheimia*, and *Thecideum*.

Crustacea, Polyzoa (rarely), and Annelides are likewise found in the Marlstone. Echinodermata as a rule are not abundant. Crinoidal fragments however enter largely into the composition of certain beds of Marlstone, and some of the hard beds of calcareous sandstone in the lower strata yield *Ophioderma*, *Tropidaster* and *Uraster*. Corals are represented by occasional species of *Montlivaltia*, *Thamnastræa*, and *Thecosmilia*. Sponges have been recorded, and many species of Foraminifera have been identified.

The Flora is at present mainly indicated by the occurrence of undetermined "plant-remains" and lignite.

MIDDLE LIAS FOSSILS.

FIG. 54.

FIG. 55.

FIG. 54. *Ammonites margaritatus*, Mont, ⅔.
„ 55. „ *spinatus*, Brug., ⅔.

## Middle Lias Fossils.

Fig. 58.

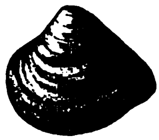


Fig. 56.

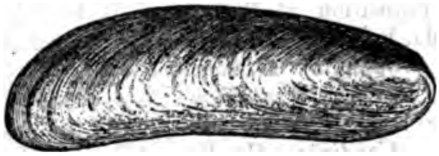


Fig. 57.


Fig. 59.

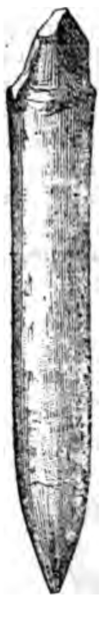


Fig. 60.

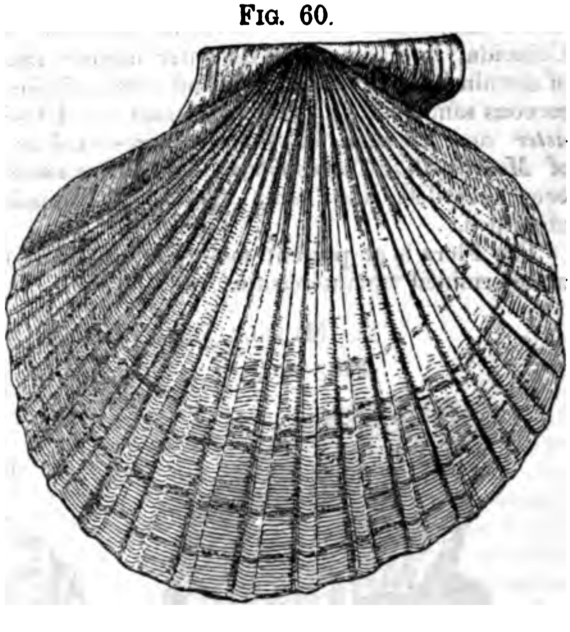


Fig. 56. *Modiola scalprum*, Sow., ½. Lower and Middle Lias.
,, 57. *Gryphæa cymbium*, Lam., ½ Lower and Middle Lias.
,, 58. *Cardium truncatum*, Sow., ⅔.
,, 59. *Belemnites paxillosus*, Schloth ½. Lower and Middle Lias.
,, 60. *Pecten æquivalvis*, Sow. ⅔.

It must be remembered that, owing to the prevalence of *Am. margaritatus* in the upper beds, the occurrence of this index-species is not to be depended upon for the identification of the zone. *A. spinatus* also (though rarely) has been recorded from the lower beds, so that the distinction between these zones is for the most part a matter of local convenience, dependent mainly on the development of the Rock Bed in the upper part of the formation. Personally I am unable to confirm the statement that *A. spinatus* occurs in the lower beds of the Middle Lias. (*See* p. 240).

The more abundant and characteristic fossils of the Middle Lias may be stated as follows:—

Zone of *Ammonites margaritatus*. (Fig. 54.)

Belemnites clavatus. (Fig. 22, p. 47.)
—— elongatus.
Arca Stricklandi.
Avicula (Monotis) inæquivalvis (sinemuriensis).
Cardium (Protocardium) truncatum. (Fig. 58.)
Cypricardia intermedia.
Gresslya intermedia.
—— lunulata.
Leda complanata.
Modiola scalprum. (Fig. 56.)
Pecten lunularis (liasinus).
Pholadomya ambigua.
Pleuromya costata.
Plicatula spinosa. (Fig. 31, p. 50.)
Ditrupa circinata.
Ophioderma Egertoni. (Fig. 64.)
,, Milleri. (Fig. 65.)

MIDDLE LIAS FOSSILS.

FIG. 61.

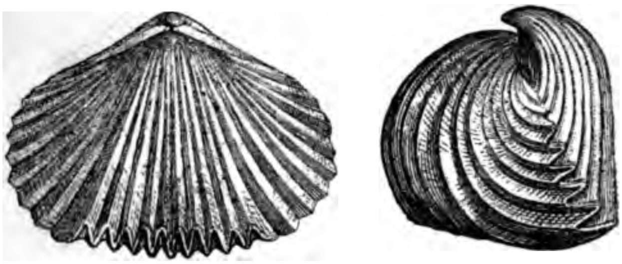


FIG. 61. *Rhynchonella tetrahedra*, Sow. (nat. size).

## Middle Lias Fossils.

Fig. 64.

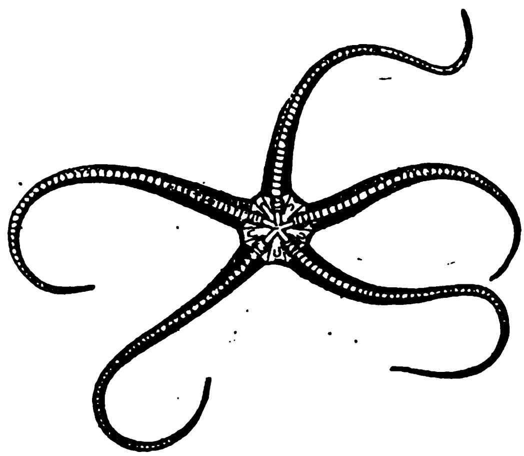


Fig. 62.

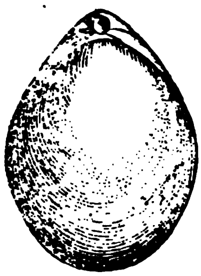


Fig. 63.

Fig. 65.

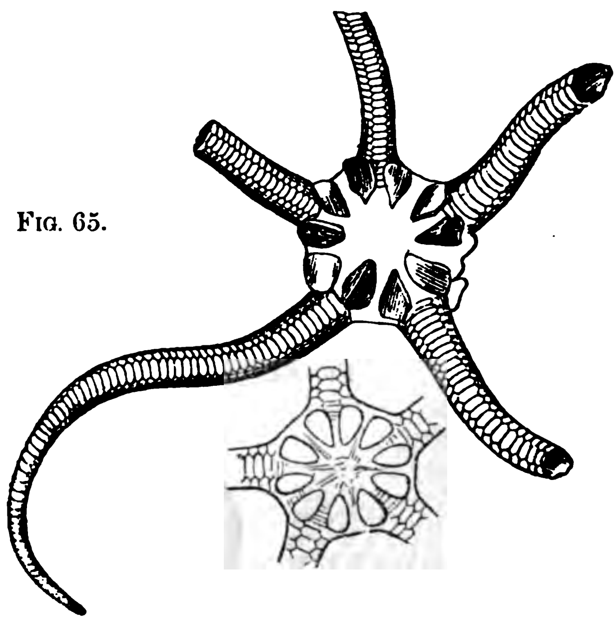


Fig. 62. *Terebratula punctata*, Sow. (nat. size).
,, 63. *Serpula tetragona*, Desl. × 2.
,, 64. *Ophioderma Egertoni*, Brod. $\frac{2}{3}$.
,, 65. ,, *Milleri*, Phil. $\frac{2}{1}$.

*Zone of Ammonites spinatus.* (Fig. 55.)

Ammonites Engelhardti.
—— fimbriatus.
—— margaritatus. (Fig. 54.)
Belemnites breviformis.
—— compressus.
—— elongatus.
—— paxillosus. (Fig 59.)
Nautilus truncatus.
Cerithium ferreum.
Cryptænia expansa.
Pleurotomaria anglica. (Fig. 27, p. 49.)
—— rustica.
Trochus lineatus.
—— pethertonensis.
Turbo rugiferus.
Dentalium elongatum.
Avicula inæquivalvis.
Cardinia concinna.
Cardium truncatum. (Fig. 58.)
Goniomya hybrida.
Gresslya intermedia.
Gryphæa cymbium (Maccullochi). (Fig. 57.)
—— gigantea.
Hinnites abjectus.
—— velatus.
Lima pectinoides.
—— punctata.
Modiola scalprum. (Fig. 56.)
Ostrea sportella.
—— submargaritacea.
Pecten æquivalvis.* (Fig. 60.)
—— dentatus.
—— lunularis.
—— textorius.
Pholadomya ambigua.
Pleuromya costata.
Unicardium cardioides.
—— subglobosum.
Rhynchonella acuta.
—— amalthei.
—— serrata.
—— tetrahedra. (Fig. 61.)
Spiriferina rostrata.

* Dumortier uses this species to characterize the beds—terming them the zone of *Pecten æquivalvis.*

Terebratula punctata. (Fig. 62.)
Waldheimia indentata.
—— quadrifida.
—— —— var. cornuta.
—— resupinata.
—— subnumismalis.
Diastopora oolitica.
Ditrupa quinquesulcata.
Serpula tetragona. (Fig. 63.)
Pentacrinus lævis.

# MIDDLE LIAS.

## Local Details.

### *Dorsetshire.*

The general character of the Lias cliffs on the Dorsetshire coast has already been pointed out (p. 54). In these cliffs the Middle Lias exhibits the following subdivisions :—

**Upper Lias.** Compact pale yellow and pink limestone, joined to the layer below, and forming a Junction-bed.

| | | | | Ft. | In. |
|---|---|---|---|---|---|
| Middle Lias. | Zone of *A. spinatus.* | Marl-stone. | 11. Brown and greenish-grey noduler and iron-shot limestone - | 0 | 9 |
| | | Yellow Sands, &c. | 10. Grey marly and sandy clays, with indurated bands - - | 10 | 0 |
| | | | 9. Yellow and brown micaceous sands, with huge indurated masses or Doggers - - - | 50 | 0 |
| | | | 8. Bluish-brown micaceous sandy clays - - - - | 16 | 0 |
| | | | 7. Hard blue and brown ferruginous sandy limestone (Margaritatus-stone of Mr. Day) - - | 1 | 0 |
| | Zone of *A. margaritatus.* | Laminated Beds. | 6. Blue and grey laminated micaceous sands and clays, with nodules and bands of hard flaggy micaceous sandstone - | 30 | 0 |
| | | | 5. Hard bluish-grey shelly and sandy limestone, with Pentacrinites: in one or two beds 1 5 | to 2 | 3 |
| | | | 4. Blue and brown micaceous sands, clays and sandy marls with ferruginous layers and small ironstone-nodules, and occasional nodules or lenticular beds of blue limestone - | 40 | 0 |
| | | Blue clays, &c. | 3. Starfish-Bed. Hard greenish-grey micaceous and calcareous sandstone - - - - | 4 | 6 |
| | | | 2. Bluish-grey micaceous marl and clay, with occasional indurated bands and nodules of grey earthy limestone - - | 155 | 6 |
| | | | 1. Three Tiers. Three thick bands of fissile micaceous and calcareous sandstone, separated by micaceous sandy clay with concretionary masses of calcareous sandstone - - | 35 | 0 |
| | | | | 345 | 0 |

**Lower Lias.** Green Ammonite Beds.

These beds vary a little in detail at different points, while measurements vary also, perhaps owing to the beds being more compressed in some places than in others, and to the irregular passage from one type of sediment to another.

In passing eastwards from Lyme Regis, we find traces of the lower beds of the Middle Lias in Stonebarrow and Westhay Cliffs. Tumbled blocks of the Three Tiers may be observed here and there above the platform formed by the "Green Ammonite" and "Belemnite Beds," but the strata between the higher and lower cliffs are much obscured by a wreck of Cretaceous material.

In Golden Cap the lower beds of the Middle Lias are well exposed in the central portions of the cliff. About 80 feet from the base, the Three Tiers stand out prominently above the Green Ammonite Beds, and form ledges over which several springs fall after traversing gullies in the overlying clay. Large tumbled blocks of these Tiers and other rocks protect the base of the cliffs and form a small headland. (See Fig. 41, p. 52.)

The various divisions and their fossils have been described in much detail by Mr. E. C. H. Day,* with whose measurements my own for the most part agree. The term "Three Tiers" was applied by him, to three massive layers of fissile micaceous and calcareous sandstone, which form a conspicuous feature in the lower part of the high cliffs of Golden Cap. The stone is of much the same character as the "Starfish Bed" which occurs at a higher horizon, but the Three Tiers are more flaggy. The Tiers are each from 2 feet to 4 feet 6 inches in thickness, and are separated by 10 to 12 feet of micaceous sandy clay, containing concretionary masses of calcareous sandstone. The entire thickness of these strata varies from 30 to 40 feet. I obtained, through the late Robert Hunter, one specimen of *Ammonities margaritatus* from these beds, and Mr. Day has noted the occurrence in them also of *A. fimbriatus*, *A. Loscombei*, and bones of Saurians.

Above the Three Tiers we have a considerable thickness of blue micaceous marls, containing ironstone-nodules, iron-pyrites, and small irregular limestone nodules. Mr. Day notes the occurrence of *Ammonities Loscombei* in these beds, as well as *A. margaritatus*. At a height of about 95 or 100 feet above the Tiers, there is a nodular bed of bluish-grey micaceous and calcareous sandy rock, rather shaly in the upper part and about 3 feet in thickness. It is conspicuous in Golden Cap. *Pentacrinus*, *Belemnites*, and *Lucina* occur in the bed. Between this nodular bed and the Starfish Bed, there are about 60 feet of micaceous marls, with occasional indurated bands and nodules of grey earthy limestone. The entire thickness, about 160 feet, is represented in Golden Cap; but at some points this estimate appears to be excessive.

Above these blue marls and clays come the Starfish Bed, and the lower portion of the Laminated beds,† which lie beneath the

* Day, Quart. Journ. Geol. Soc., vol. xix. p. 278; see also Wright, Lias Ammonites (Pal. Soc.), pp. 89, 90.

† These are the "Sands" shown beneath the Upper Greensand, in Horizontal Section, Sheet 29.

Cretaceous covering that forms the upper part of Golden Cap. The higher portions of the Middle Lias can however be studied to more advantage in Down Cliffs and Thorncombe Beacon, east of Seatown. Here the lower portion of the cliffs consists of blue clays yielding *Ammonites margaritatus*, thus differing from the clays at the base of the cliffs under Golden Cap, where *A. latæcosta* was the characteristic fossil. A fault with a downthrow of from 190 to 200 feet accounts for this change, for the Three Tiers are depressed beneath the sea-level, and we find only the upper portion of the overlying blue clays exposed to view. Here, as at Golden Cap, the beds undulate a little, and while there they present a gentle synclinal which may have helped to preserve the hill, at Down Cliffs and Thorncombe Beacon there are two undulations, but the beds on the whole are more distinctly inclined towards the east. Thus the thickness of the blue clays under the higher portions of these cliffs, varies from 50 to 90 feet, decreasing eastwards to about 35 feet at Eype. Many small and often fragmentary specimens of *A. margaritatus* may be obtained, sometimes partially embedded in the limestone-nodules. *Belemnites elongatus, Leda graphica*, &c. also occur, together with *Ammonites Bechei, A. Loscombei, Belemnites elongatus, Amberleya, Trochus, Dentalium etalense, Cardium, Cypricardia, Pleuromya costata, Plicatula spinosa, Unicardium globosum* ?, and *Rhynchonella serrata*; fossils which I obtained from the lower clays exposed between Seatown and Eype, and which were identified by Messrs. Sharman and Newton.

Mr. Day noticed a band of shelly marl beneath the Starfish Bed, and obtained from it a number of fossils, including *Pleurotomaria anglica* and other Gasteropods, *Cucullæa, Hippopodium, Waldheimia cornuta, Cidaris, Pentacrinus*, &c.*

The Starfish Bed forms a marked layer above these blue clays. It is a thick and somewhat nodular or interrupted bed of greenish-grey micaceous and calcareous sandstone, stained pink or red in places. It attains a thickness of 4 feet 6 inches. The upper portion of the masses of rock, is more or less irregular and rounded, and sometimes the top layer for 4 or 5 inches splits off. The lower surface of the stone is quite smooth and flat, and this splits off in thin layers in places. Large blocks of this rock in irregular pentagonal and quadrangular masses, sometimes 8 feet across, occur on the slopes, or lie strewn on the beach between Seatown and Eype; and where the smooth lower surface of the bed lies uppermost and can be examined, it will be seen to be characterized by numerous oblong or square holes, extending an inch or more into the dense rock. These are spaces whence the Starfishes have been chiselled out by fossil-collectors. Hardly a trace of these organisms has escaped them—even the blocks a short distance out at sea have yielded up their fossil treasures. These fallen blocks, as well as tumbled material from other beds, form a protecting fringe along the coast. Ferruginous springs are thrown

* Quart. Journ. Geol. Soc., vol. xix. p. 292.

out at the base of the Starfish Bed as well as at other levels in the cliffs. The position of the Starfish Bed as a part of the Lias, was noted by Lonsdale.* Two species are recorded from it, *Ophioderma Egertoni* and *O. tenuibrachiata.* (See Fig. 64.)

Above the Starfish Bed, come the Laminated Beds, a series of micaceous and ferruginous sandy clays and marls (the "Grey and Brown Sands with Nodules" of Mr. Day) having in places a banded appearance; and these beds, which throw out ferruginous springs, are surmounted by more distinctly laminated micaceous sands and clays, with bands of hard micaceous and flaggy sandstone, that exhibit current-bedding and occur in isolated masses. The full thickness of these beds, from the Starfish Bed to the base of the Yellow Sands, is about 90 feet.

Between these beds there is a layer of hard bluish-grey shelly and sandy limestone, occasionally separating into two beds, and from 1 feet 5 inches to 2 feet 3 inches in thickness. It occurs about 100 feet up in Down Cliff, about 130 feet up under Thorncombe Beacon, and is seen also in Eype Cliff. It contains *Pentacrinus gracilis* and Starfish, and is sometimes made up of fragments of these organisms. Mr. Day notes the occurrence of *Gryphæa cymbium, Pecten æquivalvis,* and *Plicatula spinosa* in these beds.† I have found *Ostrea irregularis* at Eype.

On the top of the Laminated Beds there is a hard blue and reddish-brown ferruginous sandy limestone, fissile at the base, occurring at a height of about 200 feet in Down Cliff. It forms a conspicuous red band about 1 foot in thickness. Among the fossils, which can be best obtained from fallen blocks, are *Belemnites, Gryphæa cymbium, Lima, Pecten æquivalvis, Spiriferina pinguis, Rhynchonella serrata,* &c.‡ This is the "Margaritatus stone" of Mr. Day, and he notes the occurrence in it also of *Ammonites fimbriatus, A. margaritatus, Nautilus, Plicatula spinosa, Rhynchonella tetrahedra, Waldheimia quadrifida,* &c.

Above it there is a band of pale bluish-brown or light grey clay, from 6 to 20 feet thick; this is overlaid by the Yellow Sands, the downwash from which in some places obscures this otherwise conspicuous band.

The Yellow micaceous sands ("Brown Sands and Sandstones," of Mr. Day) resemble those at the base of the Inferior Oolite, and were indeed included in that formation in De la Beche's section of the cliffs.§ These sands are often cemented into a hard rock, in bands with ferruginous joints, and in the form of huge rounded concretionary masses or Doggers, of which many examples are to be seen on the foreshore. The beds do not, however, exhibit the marked alternate bands of sand and sandy limestone which characterize the Midford Sands at Bridport

* See Broderip, Trans. Geol. Soc., ser. 2. vol. v. p. 174. A specimen of *Ophioderma Egertoni* was figured in the London Geological Journal (1847), Plate 19, as from the "Inferior Oolite" of Dorset.

† Quart. Journ. Geol. Soc., vol. xix. p. 292.

‡ See also J. F. Walker, Rep. Brit. Assoc. for 1890, p. 799.

§ Trans. Geol. Soc., ser. 2, vol. i., Plate viii.

Harbour. They vary from 40 to 55 feet in thickness, and extend throughout the Down and Thorncombe Cliffs, obscured here and there by a downwash of blue clay from the Upper Lias above.

Above the sands there is another band of grey marly and sandy clay, 10 or 15 feet thick, which is overlaid by the rock-bed that forms a junction between the Middle and Upper Lias.

Mr. Day has recorded from these sandy strata *Ammonites Bechei*, *A. spinatus*, *Nautilus*, *Belemnites*, *Avicula*, *Goniomya*, *Pecten*, *Pinna*, and *Plicatula*.*

The Junction-bed of the Middle and Upper Lias is made up of two layers, the upper of which consists of compact pale pink, yellow, or cream-coloured limestone with irregular surface; it is much iron-stained in places, and from 1 foot 4 inches to 2 feet 6 inches in thickness; from this portion I have obtained *Ammonites bifrons*, *A. striatulus*, *A. serpentinus*, and *Belemnites*.

The lower layer is a bed of brown, grey and greenish-grey iron-shot limestone with nodules, about 8 inches in thickness: it contains *Rhynchonella acuta*, *Belemnites compressus*, &c. A marked ferruginous seam divides these layers, and aids the splitting up of the rock. Mr. Etheridge in 1861 detected Upper Lias fossils in the upper part of this band of rock, and a short time later Mr. Day discovered Middle Lias fossils in the lower lower portion of the bed.

The fossils, perhaps, have not always been collected with a due regard to their precise position in this Junction-bed; and the following Ammonites are said to occur throughout it, in both Middle and Upper Lias:—*A. communis*, *A. serpentinus*, *A. crassus*, *A. annulatus*, and a form recorded as "*A. radians*" by Mr. Day, probably the same as that here noted as *A. striatulus*.†

It is impossible to collect from this bed *in situ*, owing to its inaccessible position, but one can climb up near enough to examine its position and general characters: while on the beach after a little experience, this and other beds can be readily identified among the tumbled blocks.

The same Junction-bed may however be seen in a brickyard and in the road-cutting north of Allington, where the section is as follows:—

| | | |
|---|---|---|
| Upper Lias. | Brown and blue micaceous and sandy marls - - - | 6 feet shown. |
| | Pale compact and pink-stained limestone - - - | 9 in. to 1 ft. 6 in. |
| Middle Lias. | Brown and blue ironshot limestone with veins of calc-spar - | 8 in. to 11 in. |
| | Brown sandy micaceous marls with *Belemnites* - - | 3 ft. 6 in. to 4 ft. |
| | Brown and blue ironshot limestone with *Belemnites*, *Rhynchonella* - - - | 10 in. |
| | Yellow sandy micaceous marls - | 4 ft. shown. |
| | Yellow micaceous sands. | |

* Quart. Journ. Geol. Soc., vol. xix. p. 293.

† Day, Quart. Journ. Geol. Soc., vol. xix. p. 284.

Here the upper portion of the junction-bed contains *Ammonites bifrons*, *A. serpentinus*, *A. striatulus*, and *Belemnites*.* Mr. J. F. Walker also records from this bed *Rhynchonella Bouchardi* and *Waldheimia Lycetti*. The clayey beds both above and below the rock-beds are worked in places for brick-making. From the lower rock-band (in which I obtained *Rhynchonella*), Mr. Walker has since recorded *R. tetrahedra* var., *R. furcillata*, *Waldheimia perforata*, &c.

The ferruginous seam that divides the Upper Lias stone from the Marlstone is probably the decomposed surface of the Marlstone; it varies from one to two or more inches in thickness, and contains in places a number of Gasteropods—hence the name *Pleurotomaria*-bed, applied by Mr. Day. The Marlstone contains waterworn stones perforated by Lithodomi and coated with Serpulæ—features noticed by Buckland and De la Beche, and which, as Mr. Day has remarked, point to a sea-bottom upon which, for a time, little or no deposit took place.†

The admixture of Upper Lias species in the Marlsone, naturally suggests some re-arrangement of the bed in Upper Lias times, but the occurrence of *A. communis* in the Marlstone is not peculiar to this area, and indicates a blending of the Middle and Upper Lias faunas, such as we find in the Transition Bed near Banbury. (See p. 229.) The species recorded from the Marlstone and *Pleurotomaria*-bed, include the following:—

| | |
|---|---|
| Belemnites. | Cardium truncatum. |
| Pleurotomaria bitorquata. | Cardinia concinna. |
| —— mirabilis. | Gryphæa cymbium. |
| —— pinguis. | —— gigantea. |
| —— precatoria. | Rhynchonella acuta. |
| —— procera. | —— serrata. |
| —— rustica. | —— tetrahedra. |
| Discohelix sinister. | Terebratula punctata. |
| Trochus Ægion. | Crinoids. |
| —— Epulus. | |

East of Eype the cliff again exhibits a portion of the Middle Lias. At the base, there are blue clays with *Ammonites margaritatus*, and these are succeeded by the Starfish Bed, the Laminated beds, and Yellow sands. These are capped by grey shaly beds, that include a hard band that may be the Junction-bed of Middle and Upper Lias, with perhaps some portions of the overlying Upper Lias. The highest strata were however difficult of access. These beds extend but for a short distance, for a fault, having a downthrow of at least 425 feet, brings them abruptly against the Fuller's Earth and Forest Marble—a fact which shows that the faults along this coast do not always produce lines of weakness that have originated valleys.

Excepting in the hard beds, fossils are not very abundant in the Middle Lias of this district; but here, as in other places, there is no marked division between the zones of *Ammonites margari-*

* See also J. F. Walker, Rep. Brit. Assoc. for 1890, p. 799; Geol. Mag., 1892, p. 440.

† Quart. Journ. Geol. Soc., vol. xix. p. 294. See also Buckland and De la Beche, Trans. Geol. Soc., ser. 2, vol. iv. p. 31.

*tatus* and *A. spinatus*. The *Margaritatus*-stone, together with the highest beds, present characters resembling the Marlstone of other places, and the fossils also lead me to include this portion of the series in the zone of *Ammonites spinatus*; leaving the underlying beds down to the Three Tiers in the zone of *A. margaritatus*. The range of *A. Loscombei* and *A. Bechei* into these lower beds of the Middle Lias is noteworthy, but I am unable personally to confirm it. (See p. 203.)

The Three Tiers form locally a good division between Lower and Middle Lias, but these bands have nowhere been identified inland, and, as before noted, the rock might easily be confused with the Starfish Bed. Near Banbury there are some hard bands in the lower beds of the Middle Lias that recall the Starfish Bed of the Dorsetshire coast.

In tracing the Middle Lias inland in Dorsetshire we have, as before mentioned, few sections to guide us in fixing the boundary with the Lower Lias, while the Upper Lias clay is not sufficiently well-marked to have been distinguished on the Geological Survey Map. Moreover the area between Beaminster and Bridport is much faulted, so that when isolated exposures of micaceous sands are to be seen it is difficult at once to determine whether they belong to the Middle Lias or to the Midford Sands. Thus north of Watton Hill, Bridport, a lane-cutting showed micaceous yellow sand and rock-sand, overlaid by hard beds of micaceous and calcareous sandstone—these beds pass under the Upper Lias beds exposed in the brickyard north of Allington, and are thus of Middle Lias age, although represented on the Survey Map as Midford Sands.

The Marlstone Junction-bed was observed by Mr. Bristow on the road leading from Bothenhampton to Shipton Gorge, and about half-way between the two churches: but it is so thin that it is rarely seen until we reach the district near Ilminster and Yeovil. In 1887 the same bed was found by Mr. J. F. Walker in Shipton Long Lane. The Marlstone (1 ft.) contained *Ammonites spinatus*, and was overlaid by a conglomeratic bed, containing *A. bifrons*, *A. communis*, and worn specimens of *A. falcifer*. Similar beds were noted by Mr. Walker in a deep cutting in Shute's Lane, Symondsbury.*

The micaceous sands are well shown in some of the deep lane-cuttings in Dorsetshire, one of the most remarkable of which is between Colmers Hill and Leazacre, at Symondsbury near Bridport. The cutting shows micaceous yellow sand with hard bluish calcareous sandstone in places.

Through Dorsetshire and Somersetshire the boundary of Lower and Middle Lias, as represented on the Geological Survey Map, has been taken approximately where the more marked feature occurs at the base of the comparatively porous sandy shales of the Middle Lias, and about the horizon of the Starfish Bed of the coast section, as the underlying blue clays throw out strong

* Geol. Mag., 1892, p. 440.

springs. Thus portions of the zone of *Ammonites margaritatus* have been included in the Lower Lias, for when the boundary was surveyed, attention was not paid to palæontological horizons.

Even if fossils were taken as the guide, the boundary could only be traced hypothetically over the greater part of the area, for sections are few and far between, and fossils are not always to be had when wanted. Thus near Chard, my colleague Mr. Clement Reid and myself, when engaged in re-surveying portions of the area, hesitated to interfere with the boundary of Lower and Middle Lias from the absence of any reliable guides in fixing the junction. In the area mapped as Middle Lias from Bridport, by Pillesdon and Lewston Hills, to Ford Abbey and Chard, there is little evidence beyond micaceous sand and sandy shales, with occasional bands of calcareous sandstone. The brickyard at Chalkway, north of Winsham, opened in laminated micaceous clay and sand, afforded no fossils; while a well at Avishay, near Chaffcombe, sunk through sandy loam and blue clay with pyrites, to a depth of 45 feet, tells us again only the nature of the strata.

*Somersetshire.*

Further north, more evidence is obtainable, for the Marlstone becomes sufficiently well-developed to be quarried. In the neighbourhood of Ilminster, the home at one time of Charles Moore, there are many sections, and the strata and their fossils have been described in much detail by that geologist.* The following is the general section of the beds beneath the Upper Lias at Ilminster:—

| | | | Ft. | In. |
|---|---|---|---|---|
| Middle Lias. | Marlstone. | 6. Pale earthy and sandy limestone with large *Belemnites* - - - | 0 | 5 |
| | | 5. Greenish and ferruginous sandy marl with *Belemnites paxillosus* - - | 0 | 4 |
| | | 4. Brown sandy and iron-shot limestone in thick beds, (the workable stone of the district) with many fossils - - 8 0 to | 12 | 0 |
| | | 3. Sands with ironstone-nodules - - - | 20 | 0 |
| | | 2. Yellow micaceous brick-marls with sandstones; *Ammonites margaritatus* - - - - | 30 | 0 |
| | | 1. Blue and grey micaceous marls with intercalated nodular sandstones - - - - | 100 | 0 |

The details of the beds below the Marlstone are given on the authority of Moore.† These beds may be compared with the yellow sands and laminated beds of the sections at Thorncombe Beacon.

In the railway-cutting at Donyatt, blue and brown micaceous sandy beds, with a layer of hard sandy limestone, were shown resting on blue micaceous sandy clay, and dipping a little to the east of south. A cutting by the old canal (south of the tunnel)

* See Memoir of C. Moore, by the Rev. H. H. Winwood, Proc. Bath Nat. Hist. Club, vol. vii. p. 232.

† See list in Proc. Somerset Arch. and Nat. Hist. Soc., vol. xiii. p. 120.

showed 15 feet of laminated micaceous sandy clay, with bands of very tough bluish nodular limestone, containing much iron-ore. I obtained no fossils from these beds, but according to Moore they belong to Group 1 of the above section, and he records *Ammonites Bechei* from beds on the same horizon at "Haslewell" [? Ashwell]. It is noteworthy that Mr. Day obtained "two crushed fragments of *Ammonites Bechei*" from sandstone in the Yellow Sands near the top of the Middle Lias on the Dorsetshire coast.*

A pit at the brickyard south of Ilminster (probably the section at Cross, mentioned by Moore), showed blue micaceous sandy clays with *Ammonites margaritatus*; and at Ashwell, north of Ilminster, beds of micaceous sands with hard sandy limestone have been opened up. Moore has published a list of species from the former locality.†

The Marlstone has been opened up in quarries on the north of Ilminster, at Tortwood Hill and Moolham, and to the north of Down Lane, east of Donyatt. The rock consists of irregular beds of reddish-brown iron-shot limestone, sometimes sandy and micaceous, yielding *Ammonites spinatus A. margaritatus, A. Engelhardti, Belemnites breviformis, B. compressus, B. cylindricus, B. paxillosus, Pholadomya ambigua, Pecten æquivalvis, Gryphæa cymbium, G. gigantea, Pleuromya costata, Rhynchonella acuta, R. tetrahedra, R. serrata, Terebratula punctata, Waldheimia quadrifida* var. *cornuta*, and *W. resupinata*.

Moore has given a long list of species from the Marlstone of Ilminster including Plant-remains, Sponges, Foraminfera, Echinodermata, Crustacea, Fishes (*Hybodus* and *Lepidotus*), and Saurians (*Ichthyosaurus*). Numerous Gasteropods are recorded, and these include species found in the Transition Bed of Northamptonshire (see p. 229). Two species of *Cryptænia* (*C. rotellæformis* and *C. expansa*) occur also in the Marlstone of the Dorset coast. Of *Pleurotomaria* Moore obtained one example "2 ft. in circumference by 7½ in. in height."‡

The fact that the uppermost band of Marlstone, which is sometimes much iron-stained, is separated from the main mass of the rock by a few inches of sandy marl or clay, is a general feature in this neighbourhood. The stone is quarried to a depth of from 5 to 10 feet, a ferruginous sandy clay being usually met with at the base of the stone-beds. The rock has been used for building-purposes, it forms a durable material, and is locally known as the "Moolham Stone." It has also been burnt for lime; but it is more commonly employed for road-mending.

The Marlstone has been extensively quarried at Boxtone Hill and Hurcot, between Sevington St. Mary and Stocklinch Ottersey, and at Shepton Beauchamp, where it exhibits the same general characters as at Ilminster, although somewhat reduced in thickness.

* Quart. Journ. Geol. Soc., vol. xix. p. 293.
† Proc. Somerset, Arch. and Nat. Hist. Soc., vol. xiii. p. 162.
‡ *Ibid.*, pp. 164, &c.

The lower beds, comprising sands and dark blue and brown sandy clays, with tough blue cement-stone nodules, were exposed in the road-cutting west of Hurcot. At New Cross, and to the south of West Lambrook, loamy micaceous clays, like the beds at Mudford near Yeovil, have been worked to a depth of 6 feet, for the manufacture of red bricks and drain-pipes. The total thickness of these lower beds may be about 150 feet.

At South Petherton the sands below the Marlstone, as observed by Moore, are well shown at the end of North Street, in the hill descending towards Martock. Eastwards we find few sections of the lower beds, but they form a fertile tract, and the soil is well adapted for orchards, the cider of Tintinhull being of local repute. Here and there as at Sock, we find laminated micaceous and sandy shales, with calcareous bands and nodules of ochre and "race"; and these beds rest on clays which throw out springs. Much of the ground about the junction of the Middle and Lower Lias is heavy and wet in winter-time, and many of the footpaths by the roadsides at Chilthorne Domer, and Tintinhull are raised, and paved with slabs of Lower Lias, owing to the wet and muddy state of the roads. South of Mudford there are two brickyards, where bricks, drain-pipes, and flower-pots are manufactured. The beds consist of about 6 feet of brown loamy clay with thin bands of micaceous ironstone; but no fossils appear to be preserved.

At South Petherton the Marlstone (3 feet 6 inches thick) has been extensively quarried, and from a section on the north side of the town, were obtained many of the Brachiopoda, figured by Davidson, from the Middle Lias. Moore remarks that the organic remains are here especially abundant, and on the whole in better preservation than in most other localities.* Dr. Wright mentions that the best specimens of *Ammonites margaritatus* and *A. Engelhardti* came from this locality.† Fine examples of *Pleurotomaria anglica* have also been obtained.

A pit west of Norton, near Ham Hill, showed the following section:—

| | | Ft. In. | Ft. In. |
|---|---|---|---|
| Upper Lias (Basement Beds). | Brown ochreous and loamy clay, with dark brown clay at the base, resting in pipes on the bed below - | 2 0 to | 3 0 |
| | Rubbly light earthy limestone and marl, with *Ammonites communis*, *A. bifrons*, *A. serpentinus*, *Rhynchonella Bouchardi*, &c. - - | - | 7 0 |
| Middle Lias. (Marlstone). | Pale earthy and iron-shot limestone, passing down into blue and brown iron-shot limestone, crowded in places with Belemnites and other fossils (base not shown) - | 1 6 to | 2 0 |

The Marlstone has also been quarried to the east of Holy Tree, where it is 2 feet 6 inches thick. In this neighbourhood it is known as "Due Stone,"‡ a term applied to a somewhat similar

* Proc. Somerset Arch. and Nat. Hist. Soc., vol. xiii. p. 137.

† Lias Ammonites (Palæontogr. Soc.), p. 95.

‡ This term, as elsewhere noted (p. 296), is probably of Celtic origin (Dhu Stone).

rock at the base of the Inferior Oolite. The rock becomes more attenuated east of Montacute station, north-east of Preston, and near Brimsmoor Tree, north of Yeovil; being reduced to 1 foot 6 inches or 1 foot in thickness. At Preston the rock (a hard iron-shot limestone) contains a few small pebbles of quartzite, but it is said to burn to a "wonderful good lime," and here as elsewhere it is used for road-metal.

The Rock-bed rests on micaceous sandy loam or shales, and owing to its poor development it forms no prominent feature, the escarpment north of Yeovil being mainly formed of the underlying micaceous sandy shales. It may, however, be traced south of Longcroft, by the lane that leads to Brimsmoor Tree. Southwards the ground very nearly corresponds with the dip-slope, so that as far as the high-road between Yeovil and Preston, the Rock-bed is reached in several places beneath a few feet of Upper Lias. (See Fig. 66.)

It is noteworthy that the Rock-bed, where it comes to the surface, is much piped or furrowed by the action of carbonated water, the residue being a brown ferruginous loam. In places it may be entirely decomposed at its outcrop; and as the Upper Lias basement-beds are not very thick or durable, and are overlaid by laminated micaceous sandy shales, resembling the beds below the Rock-bed, it becomes exceedingly difficult to trace a boundary between the Middle and Upper Lias, where there are no sections, as in the tract north-east of Yeovil. This explanation probably accounts for the difficulties met with between Bridport and Chard.

The pale earthy limestones of the Upper Lias rest in places directly on the Marlstone near Yeovil, and sometimes form one block, as in the coast-section at Thorncombe Beacon. The united thickness of these stone-beds is about 7 feet, and they have furnished a limited supply of water to wells in the immediate neighbourhood of Yeovil. (See p. 315.)

The following species of fossils were collected by Mr. J. Rhodes and myself from the Marlstone near Yeovil, north-east of Preston and at Brimsmoor Tree; and they were identified by Messrs. Sharman and Newton:—

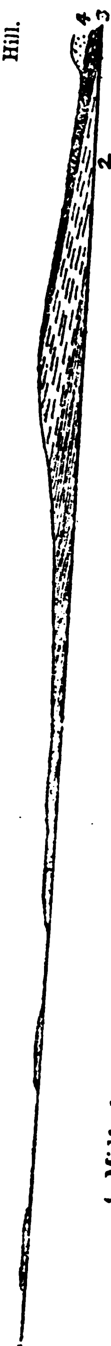
Ammonites Engelhardti.
—— margaritatus.
—— spinatus.
Belemnites ventralis ?
Amberleya.
Arcomya.
Avicula inæquivalvis.
Cardinia concinna.
Gryphæa cymbium.
—— gigantea.
Lima punctata.
Pecten æquivalvis.
—— demissus.
Pecten (allied to) dentatus.
—— julianus ?
—— lunularis.
Pinna Hartmanni ? (cast).
Pleuromya costata.
Unicardium globosum.
Rhynchonella acuta.
—— tetrahedra.
Spiriferina rostrata.
Terebratula subpunctata.
Waldheimia quadrifida var. cornuta.
—— resupinata.

There is an example of *Ostrea sportella* from South Petherton in the Woodwardian Museum at Cambridge. This fossil is more abundant in the Marlstone of Banbury.

FIG. 66.

*Section from Ilchester to Pen Hill, Yeovil.*

Distance about 5 miles.




4. Midford (or Yeovil) Sands.
3. Upper Lias (Clays and Sandy Shales.)
2. Middle Lias (Rock-bed, Sands, and Sandy Shales).
1. Lower Lias (clays).

At Trent, north-east of Yeovil, the Marlstone is about 15 inches thick. A quarry north-west of Trent Barrow, exposed tough brown and grey sparry limestone, with nodules of pale compact limestone, and oolitic grains. Here, as in other places, the basement-beds of the Upper Lias are shown above the Marlstone. Further on, at Coneygore Hill, Sandford Orcas, the Rock-bed is stated to be 4 feet thick, in a section noted by Moore, and near Sutton Montis to be 6 feet, as observed by Bristow. It has been traced through Compton Pauncefoot, but no sections have been noticed near Castle Cary. The description of the beds in a section at Scale Hill, near Batcombe, by De la Beche, is probably a general one, as the Marlstone, although present, does not appear to comprise a mass of strata 21 feet thick, as stated by him.* A rock-specimen of Marlstone, micaceous and sandy limestone with *Belemnites*, *Rhynchonella*, and *Terebratula*, was obtained at Westcombe, west of Batcombe.†

Of the lower beds we have little information, beyond the fact that there is a development of micaceous sandy shales and sands, in the country extending from Trent, near Yeovil, through South and North Cadbury to Batcombe. In the valley south of Batcombe, there are brown micaceous and marly sands, with *Ammonites* very poorly preserved. Probably the Lower Lias is not exposed so near the Oolitic escarpment as represented on the Geological Survey map; but north of Batcombe the Middle Lias has not been shown on the map until we reach the neighbourhood of Bath. In the intermediate area it may be partly overlapped by Inferior Oolite and Midford Sands.

North of West Pennard Church, the lower beds of the Middle Lias are exposed in a lane-cutting, and the beds have also been exposed by the stream near East Pennard Church. The Rock-bed has been opened up beneath the Upper Lias to the east of West Pennard. The general section is as follows (see Fig. 43, p. 90):—

| | | FT. IN. |
|---|---|---|
| Middle Lias. | Hard blue and brown ferruginous oolitic, and in places compact, Marlstone, with, near the top, irregular nodules of grey earthy limestone - - | 1 3 |
| | Micaceous sands with *Belemnites*, and ochreous, clayey beds, with thin alternate layers of sand. | |
| | Thick-bedded yellow micaceous and fissile rock-sands, with ochreous galls, and occasional large concretionary masses of bluish sandy limestone - - | 40 feet or more. |
| | Bluish-grey and yellow sandy micaceous shales. | |

The lower beds, consisting of blue and brown clay with "race," and micaceous sandy shales with ferruginous concretions and occasional indurated bands, have been opened up in brickyards to the north of Glastonbury, where red bricks, tiles, drain-pipes,

* Mem. Geol. Survey, vol. i., p. 280.
† Catalogue of Rock Specimens, No 23.

flower-pots, and ornamental bricks are manufactured. A thickness of upwards of 40 feet of these beds is shown, but no fossils were to be had. They are probably on the same horizon as the beds yielding *Am. margaritatus* at Brent Knoll.

Above these beds there is a development of micaceous sands with indurated masses of sandy limestone, and blue septarian limestone, overlaid by micaceous sandy clay. These beds are to be seen at Chalice Hill and in a deep-lane leading from it; and they occur also on Wearyall Hill, which rises to a height of about 190 feet. The well-bedded nature of the sands, is similar to that of the beds exposed in the road-cutting north of South Petherton. Springs are thrown out at the base of the Sands.

The uppermost micaceous sandy clays yield Belemnites and Ammonites, and they are overlaid by the Rock-bed, blue iron-shot and oolitic limestone, from 1 to 2 feet thick.*

The Rock-bed here and at Pennard, yields *Ammonites spinatus, A. margaritatus, Belemnites, Lima, Pecten æquivalvis, Rhynchonella acuta, R. tetrahedra,* &c. Glastonbury Tor is based on a platform of Upper Lias, beneath which, and to the north of the hill, the Marlstone Rock-bed was formerly quarried in two or three places. The general section of the Middle Lias of Glastonbury is as follows (see Fig. 84, p. 263):—

| | | Ft. In. | Ft. In. |
|---|---|---|---|
| Middle Lias. | Rock-bed - - - - | 1 0 to | 2 0 |
| | Micaceous sandy clays - - - | | 10 0 |
| | Micaceous sands with indurated beds - | | 60 0 |
| | Micaceous shales - - - | | 140 0 |
| | Clay (to sea-level) - - - | | 20 0 |

Brent Knoll, which is similarly constructed, exhibits beneath the Knoll (formed of Midford Sands), a platform of Upper Lias based on Middle Lias. (See Fig. 85, p. 263.)

A well dug to a depth of 15 or 20 feet at the foot of the hill, near Brent Knoll railway-station, proved blue micaceous shale, which yielded *Ammonites margaritatus, A. Loscombei, Belemnites, Avicula,* and fragments of lignite.† The higher beds are not well exposed, but they form a comparatively steep scarp, surmounted by the Upper Lias. The Rock-bed is probably thin.

Approaching the Mendip Hills we find evidence of irregular overlap of the divisions of the Lias and Lower Oolites, and some of the beds, where present, are too thin to be represented on the Geological Survey map. Between Batcombe and the Mendip Hills, near Doulting, we have no records of the Middle Lias, although the formation may be present in an attenuated form.

In the vales of Nunney, Whatley, and Vallis near Frome, we find sometimes Rhætic Beds, sometimes Lias, and also Inferior Oolite, resting directly on the Carboniferous Limestone, and pre-

* The thickness of "about 15 feet" assigned to the Marlstone-rock by Dr. Wright, is far too great. Quart. Journ. Geol. Soc., vol. xvi. p. 34; see also Day, Proc. Cotteswold Club, vol. iii. p. 121; and H. B. W., Proc. Geol. Assoc., vol. xi. p. cciii.

† H. B. W., Proc. Bath Nat. Hist. Club, vol. vi. p. 125.

senting in places conglomeratic characters. Little would be known of the fossils of these beds, but for the researches of Charles Moore: nevertheless the testimony of the organic remains, which are sometimes obtained from fissures that may have received infillings at different periods, must necessarily be received with caution. (See p. 97.) The following section at Whatley was noted by Moore:—

| | | Ft. | In. |
|---|---|---|---|
| Clay and debris of Inferior Oolite. | | | |
| Middle Lias | Grey laminated marl | 1 | 2 |
| | Grey marl, very fossiliferous | 0 | 10 |
| Carboniferous Limestone. | | | |

He stated that "the fossiliferous marl at Whatley is in great part composed of dismembered *Pentacrinites*, but the same thin deposit has yielded 64 species of organic remains; of these the most varied are the Brachiopoda, of which there are present the genera *Argiope, Crania, Leptæna, Rhynchonella, Spiriferina, Suessia, Terebratula, Terebratulina*, and *Thecideum*."* Moore remarked that occasionally the fossiliferous marl is converted into a thin indurated limestone, difficult to separate from the older rock on which it rests.

The method of occurrence of this fossiliferous bed and its organic remains, were compared by Moore with a similar accumulation at Fontaine-étoupe-Four in Normandy, described by M. Deslongchamps, as of Middle Lias age. Upper Lias beds also occur in that country under similar conditions. (See p. 229.)

Moore observed that "within two miles of Whatley, the Middle Lias is again present under very peculiar conditions at the hamlet of Holwell. On the Carboniferous Limestone at this place, and extending as far as Cranmore, are deposits of conglomerate of Middle Lias age, almost undistinguishable lithologically from the older rocks. . . . Not only does the Middle Lias conglomerate fringe the ancient coast-line at this point, but it has been carried down for great depths into the viens and fissures of the limestone, the infillings in one of the quarries occupying nearly a third the length of the section, one of the Liassic veins being fifteen feet in breadth. From the side of this, about fifty feet from the surface, was extracted a block but a few inches square, containing fourteen species of gasteropoda of Middle Lias age, and all of them new to this country."† The lists given by Moore, from these localities of Whatley and Holwell, contain forms found elsewhere in Lower, Middle, and Upper Lias. (See p. 98.)

Moore has recorded the presence of the Middle Lias (Marlstone) at Mells, resting directly upon the Coal-measures. It was penetrated in sinking a shaft, and found to be 9 feet in thickness. It

* Proc. Somerset Arch. and Nat. Hist. Soc., vol. xiii. p. 155; and Quart. Journ. Geol. Soc., vol. xxiii. pp. 477-480.

† Proc. Somerset Arch. and Nat. Hist. Soc., vol. xiii. p. 157; Quart. Journ. Geol. Soc., vol. xxiii., pp. 482, &c.

contained *Ammonites spinatus, Belemnites paxillosus, Pholadomya ambigua*, and *Montlivaltia*. From blue marl at the same locality Moore obtained *Ophioderma Egertoni*.*

In the neighbourhood of Radstock and Camerton, there are beds of iron-shot limestone (with nodules), which yield *Gryphæa cymbium, Terebratula punctata, Waldheimia quadrifida* var. *cornuta, Rhynchonella rimosa*, &c., and have been described as Middle Lias. The Ammonites however, which include *A. armatus, A. Jamesoni*, &c., tend to show that the beds belong to the higher portion of the Lower Lias, according to the grouping adopted in this Memoir. No traces of *A. margaritatus* and *A. spinatus* have been found in these beds; but it is possible that here and there a layer of stone may be found of Middle Lias age, as in the section near Branch Huish, south-east of Radstock, described by E. B. Tawney. There the top layer of stone yields *Cardinia concinna*.†

Among the beds of the Lower Lias there is, in this area, evidence of reconstruction at different horizons, so that, as Moore has pointed out, we have presented to us conditions somewhat "abnormal," when compared with their "typical" development as uninterrupted deposits elsewhere. In his opinion the Mendip Hills, although subject to oscillations of level, formed a barrier to the incursion of the deeper-sea deposits which were taking place to the south.‡ There may also be evidence of reconstruction during the Middle Lias.

The "nodules" so frequently met with in the limestones, are sometimes slightly phosphatic, and appear in many cases to be rolled masses of previously formed Lias limestone.

There is evidence of a considerable thickness of "Blue marl" between the Lower Lias limestones and the Inferior Oolite, north of Radstock and east of Paulton. A coal-boring sunk through the Inferior Oolite on the hill east of Paulton, proved 120 feet of "Blue marl." It is highly probable that Lower, Middle, and Upper Lias are represented in this group. The evidence tends to show that the Marlstone as a Rock-bed is of inconstant occurrence in this area north of the Mendip Hills, as it is in other localities; and it is likely that the main mass of the "Blue marl" is of Middle Lias age. (See p. 127.) Further north we have evidence of blue micaceous marl, beneath a bed of "marlstone," at Dundas, where the Upper Lias clay is very thin.

The section opposite Dundas, given by Moore, is a remarkable one, and is unfortunately now obscured: the beds recorded by him are as follows§:—

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* Proc. Somerset Arch. and Nat. Hist. Soc., vol. xiii., p. 150; Quart. Journ. Geol. Soc., vol. xxiii. p. 481.

† Proc. Bristol Nat. Soc., ser. 2, vol. i., p. 186; see also De la Beche, Mem. Geol. Survey, vol. i. p. 280.

‡ Moore, Quart. Journ. Geol. Soc., vol. xxiii. pp. 454, 474, &c.; and Proc. Somerset Arch., and Nat. Hist. Soc., vol. xiii. p. 161.

§ Proc. Somerset Arch. and Nat. Hist. Soc., vol. xiii. p. 153.

| | | Ft. | In. |
|---|---|---|---|
| [Midford Sands.] | Inferior Oolite sands - - - | 20 | 0 |
| [Upper Lias.] | Grey clay - - - - - - | 2 | 0 |
| | Upper Lias stone with *Ammonites bifrons* (*Walcotti*), *A. serpentinus*, &c. - - | 1 | 0 |
| | Blue clay - - - - - - | 3 | 0 |
| | Brownish marlstone with *A. capricornus* (*maculatus*), *Unicardium cardioides*, *Lingula Beani* [?] abundant, Crustacea and Saurian teeth - - - - | 1 | 0 |
| [Middle Lias.] | Blue micaceous marl with nodules of iron-stone - - - - - - | 20 | 0 |

The occurrence of *A. capricornus* in the "brownish marlstone," together with the *Lingula*, is remarkable. Nevertheless much of the so-called "Marlstone" which is of an iron-shot character in the Radstock area, occupies a different horizon from the Rock-bed at Ilminster; and fossils of distinct stages are found sometimes together in a remanié condition. It seems reasonable to conclude that this "marlstone" of Dundas is likewise a remanié bed; and that it occurs at the base of the Upper Lias.

In the neighbourhood of Bath there are few sections in the strata between the Lower Lias limestones (Blue Lias) and the Midford Sands. Londsdale describes the beds filling this interval, as consisting of "Blue clay and marl; which are tough in the lower part of the deposit, but thinly laminated and micaceous in the upper. Irregular beds of stone are interstratified with them." He estimates the thickness at 200 feet, and an old boring at Batheaston proved a thickness there of 170 feet. (See p. 135.)

Along the Midland Railway between Bath and Combe Down, blue micaceous clay was exposed in several cuttings. It contains occasional bands of earthy limestone, but does not appear to be fossiliferous. It is capped by a bed of nodular iron-shot limestone that may represent the Marlstone, while above are three beds of limestone, the highest of which has yielded Upper Lias fossils.

These hard bands in the Upper Lias sometimes resemble the Rock-bed of the Marlstone, and were evidently included with it by Lonsdale, in his section (at Box) of the strata overlying the blue clay and marl before mentioned. Indeed he remarks that "Interposed between the lias and inferior oolite are several beds of sandy marl, to which Mr. Smith gave the name of marlstone. They effect a gradual passage from the lias into the inferior oolite."* The fact is the Upper Lias is very thin in places, and we have little more than the basement-beds, overlaid by clays of no great thickness, that merge upwards into the Midford Sands.

Thus, on the Geological Survey map near Bath, where the original survey and grouping of the divisions were undertaken primarily under Lonsdale's guidance, the Upper Lias has in some places been included with the Middle Lias, and in other places both these divisions have been included in the Lower Lias; partly no doubt on account of the steep slopes, and the little space (on the one-inch map) to show the divisions; and partly because rock-

* Trans. Geol. Soc., ser. 2, vol. iii. pp. 243, 247.

beds, being rarely shown, it was difficult to mark any division in the blue clays that overlie the Blue Lias limestones.*

The following appears to be the general section of the strata, as illustrated by sections at Box (noted by Lonsdale), Devonshire Buildings, Bath (noted by the Rev. H. H. Winwood), and by the deep boring at Batheaston:—

| | | Ft. In. | Ft. In. |
|---|---|---|---|
| Midford Sands. | Micaceous yellow sand. | | |
| Upper Lias. | Ferruginous sandy and oolitic limestone with nodules, *Ammonites serpentinus*, *A. communis*. &c. - Pale grey earthy limestones and clays - - - - | 3 6 to | 4 6 |
| Middle Lias and Lower Lias. | Marlstone (? persistent) - - | | 1 0 |
| | Micaceous yellow sand and clay, with indurated layers - - - - | | 3 0 |
| | Blue micaceous clays with occasional stone beds - - - - | about | 150 0 |
| | Blue lias limestones. | | |

The stone-beds at the junction of Middle and Upper Lias were observed by Lonsdale at Batheaston, and in the descent from High Barrow Hill to Pennyquick Bottom, near Twerton; and by William Smith at Bathampton. Moore likewise noticed the beds at Kelston Beechen Cliff, and other places in the neighbourhood of Bath.†

North of the Great Western Railway, in the lane leading from Box to Hill House, blue and brown micaceous and marly clays were exposed in a road-cutting; ochreous nodules occurred in the upper part, but no fossils were to be seen. Hill House is situated on Inferior Oolite (with *Rhynchonella spinosa*, &c.).

The principal section exposed in this region, is that at Oak's Lane, Upton Cheney, near Bitton, which was noted by Moore:—

| | | Ft. In. |
|---|---|---|
| Upper Lias. | About 12 beds with numerous specimens of *Ammonites serpentinus* - - - | 12 0 |
| Middle and Lower? Lias, 155 ft. 8 in. | Marlstone? - - - - - | 1 0 |
| | Grey and reddish-brown marls with nodules and bands of ironstone, and occasional layers with *Pecten* - - - | 144 5 |
| | Blue-hearted stone - - - - | 0 7 |
| | Shelly marlstone - - - - | 0 4 |
| | Grey marls - - - - - | 8 0 |
| | Blue micaceous stone - - - | 1 4 |

Moore records from the beds below the Upper Lias, *Belemnites*, *Gryphæa gigantea*, &c., and *Ammonites capricornus* (*maculatus*). The precise horizon of the Ammonite is not indicated, but the occurrence is noteworthy in connexion with the record he gives of this species from the "marlstone" of Dundas, p. 211.‡

The evidence of Middle Lias, and more especially of the Marlstone in the neighbourhood of Bath, is therefore by no means so satisfactory as one could wish. Moreover at Dundry we fail

* See De la Beche, Mem. Geol. Survey, vol. i., p. 275.
† Proc. Somerset Arch. and Nat. Hist. Soc., vol. xiii. p. 126.
‡ *Ibid.*, vol. xiii. p. 152.

to get evidence, and Mr. Etheridge has stated there are no traces whatever of the Middle Lias or Marlstone.*

Moore remarks that "On the top of Bitton Hill, the Upper Lias is composed of several ferruginous-looking beds of stone, with what appears to be a single bed of the Middle Lias marlstone immediately beneath."†

*Gloucestershire.*

Following the main escarpment north of Upton Cheney, we find the outcrop of the Middle Lias passing through Dyrham, Dodington, Old Sodbury, and Hawkesbury, but there are no records of sections along this tract.

Further north the Marlstone is well developed, and the Middle Lias forms a platform at Hilsley and Alderley, at Wotton-under-Edge, North Nibley, Stinchcombe, and Dursley. (See Fig. 67.)

A brickyard situated near the Chapel north of Wotton-under-Edge, showed about 30 feet of very micaceous bluish-grey and brown sandy shales. These are slightly calcareous and are indurated here and there. Pyritic nodules occur, but no organic remains were to be seen. Red bricks and drain-pipes are manufactured here, but stronger clay (Lower Lias) is brought from Bradley Green for the making of the pipes. The total thickness of the Middle Lias at Wotton-under-Edge was estimated by Bristow at 200 feet. (See Fig. 86, p. 264.)

The following section in the road from Nibley Church to Nibley Green, was recorded by Bristow:—

| | | Ft. | In. |
|---|---|---|---|
| Middle Lias. | Brown rock (Marlstone) | 12 to 14 | 0 |
| | Clay | 15 | 6 |
| | Ferruginous sandstone with *Belemnites* | 1 | 0 |
| | Bluish sandy clay | 5 | 0 |
| | Iron-band (fossils) | 1 | 0 |
| | Yellowish sand with iron balls | 27 | 2 |
| | Iron-band (fossils) | 0 | 6 |
| | Thick-bedded sandstone | 2 | 0 |
| | Sand with iron-bands | 5 | 0 |
| | Iron-band | 0 | 8 |
| | Sand | 33 | 0 |

The Marlstone has been quarried at Stancombe Park. Explorations for iron-ore have been made, near Southend Farm, south-east of North Nibley, and near Stinchcombe, but the beds are not sufficiently rich to repay the cost of working. (See p. 303.)

* Wright, Quart. Journ. Geol. Soc., vol. xvi. p. 22.
† Proc. Somerset Arch. and Nat. Hist. Soc., vol. xiii. p. 127.

FIG. 67.

*Section across the Cotteswold Hills from Wotton-under-Edge to Symond's Hall Hill, Gloucestershire.*
(Sir A. C. RAMSAY.)


7. Great Oolite.
6. Fuller's Earth.
5. Inferior Oolite.
4'. Cephalopoda Bed (top of Midford Sands).
4. Midford (or Cotteswold) Sands.
3. Upper Lias.
2'. Rock Bed - - } Middle Lias.
2. Sandy and clayey beds - } Middle Lias.
1. Lower Lias (clays).

The Marlstone has been quarried in several places near Stinchcombe Fields, where it forms a broad platform. On the high-road leading towards Tails Hill, the large quarry on the south side, showed the following section:—

| | | Ft. | In. |
|---|---|---|---|
| Upper Lias. | Pale grey clay, with nodules of pale mottled bluish-grey earthy limestone - - | 1 | 6 |
| Middle Lias (Marlstone). | Hard ferruginous sandy limestone, blue-hearted in places: with *Belemnites*, *Ammonites*, large *Gryphæa*, *Terebratula punctata*, *Rhynchonella acuta*, and *R. tetrahedra* (in clusters) - - - - | 15 | 0 |

*Avicula*, *Cardinia crassissima*, and *Pecten æquivalvis* are recorded by Moore. The beds are much shattered and broken up where not covered by Upper Lias. The stone is quarried for road-metal, and for building walls, &c

At Newnham (or "Newent") quarry south-west of Cam, the Marlstone is 20 feet thick, according to Moore. From this rock many Urchins, including *Eodiadema*, were found by Mr. Beeby Thompson and Mr. W. D. Crick. They found that the "Transition bed" (with *Ammonites acutus*) was represented, though not so clearly as in Northamptonshire.*

In the escarpment south-east of Frocester the Marlstone, according to Moore, is reduced to 2 feet in thickness, while the total thickness of the Middle Lias has been estimated at 150 feet.†

Near Stroud the Marlstone Rock-bed is not so well developed as at Stinchcombe, for it is represented by a group of micaceous sandy clays, that contain inconstant beds of hard calcareous sandstone of variable thickness, and nodular and iron-shot marlstone. These beds have been exposed at Dudbridge Mills, in an adjoining brickyard in the valley towards Nailsworth, and also in the railway-cutting by Rooksmoor Mill, Woodchester, where about 12 feet of ferruginous sandstone, overlaid by iron-shot rock with *Belemnites*, was exposed.

The following section at Dudbridge Mills, is by E. Witchell:—‡

| | | Ft. | In. |
|---|---|---|---|
| | River gravel - - - - - - | 2 | 0 |
| Middle Lias. | 10. Light brown calcareous sandstone, with *Ammonites spinatus*, *Belemnites paxillosus*, *Avicula inæquivalvis*, *Gryphæa cymbium*, *Pecten æquivalvis*, and *Unicardium cardioides* - - - - - | 3 | 0 |
| | 9. Light brown or grey shaly clay - - | 8 | 0 |
| | 8. Dark brown ferruginous rock (marlstone), with *A. margaritatus*, *B. paxillosus*, *U. cardioides*, &c. - - - - | 1 | 0 |
| | 7. Brown marly shale - - - - | 8 | 0 |
| | 6. Light brown soft sandstone, blue in the centre, with nodules and shelly layers, *Pentacrinus*, &c. - - - - | 3 | 0 |
| | 5. Blue and brown ferruginous sandy clay - | 3 | 6 |
| | 4. Dark blue clay - - - - - | 0 | 4 |
| | 3. Ferruginous nodules - - - - | 0 | 6 |
| Lower Lias. | 2. Light blue sandy clay, partly consolidated - - - - - - | 3 | 0 |
| | 1. Dark brown or bluish shaly clay - | 3 | 0 |

* Thompson, Rep. Brit. Assoc. for 1891, p. 350.
† Wright, Quart. Journ. Geol. Soc., vol. xii. p. 303.
‡ Geol. Stroud, p. 17.

In the shales No. 7, I obtained small specimens of *A. margaritatus* and *Belemnites vulgaris*. The lower beds (1 and 2) were regarded by Witchell as belonging to the zone of *A. Henleyi*; and specimens of *Pholadomya ambigua*, *Unicardium cardioides*, and *Pleuromya costata*, which occur in the pit, and apparently come from this horizon, are much like specimens from the same zone on the north of Dumbleton.

The Marlstone has been observed by Witchell at Rock Mill, and further north, in the valley between Stroud and Painswick.

Northwards along the borders of the Cotteswold Hills there are few sections in the Middle Lias; the Marlstone forms a small terrace near the foot of the hills, but the beds are best shown in the outliers of Churchdown, Oxenton, Dumbleton, and Bredon. There are no good sections on Robin's Wood Hill. At Churchdown the Marlstone has been, in former years, largely quarried for road-metal and other purposes. The beds have been described by Murchison and others,* but the best account is that by Dr. F. Smithe, of Churchdown. He describes the beds below the Upper Lias as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Middle Lias. | Yellow marly sands, with ferruginous concretions, and nodules yielding Ostracoda | 6 0 to 6 | 8 |
| | Rock-bed; impure blue limestone weathering brown, ferruginous, graduating into thin-bedded marlstone - - - - | 10 | 0 |

The yellow marly sands are grouped with the zone of *Ammonites spinatus*. They contain this and other Ammonites, *Gryphæa cymbium*, &c.

The Marlstone-rock is marked as the zone of *Ammonites margaritatus*, though no doubt it is equivalent to beds elsewhere included in the horizon of *A. spinatus*. At Ilminster and Yeovil *A. spinatus* and *A. margaritatus* occur together. Here at Churchdown Dr. Smithe has found *A. Engelhardti* (found also at Ilminster, &c.), *Pecten æquivalvis*, *Cardium truncatum*, *Rhynchonella acuta*, *R. tetrahedra*, &c.†

At Alderton and Dumbleton the thickness of the Marlstone is about 14 feet, but the beds are not now fully exposed; and further references to them will be given in the account of the Upper Lias at those localities. Fossils similar to those recorded from Churchdown have been obtained.‡ I obtained *Ammonites nitescens*, *A. spinatus*, *Belemnites breviformis*, *Modiola scalprum*, *Pecten*, and *Pleuromya costata*: these fossils were named by Messrs. Sharman and Newton. (See p. 267.)

There are no good sections of the Middle Lias in the escarpment near Cheltenham, although the beds are occasionally exposed in ravines and deep lanes. Northwards by Gretton, and again to

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* A section showing 14 feet of Marlstone, was given by Murchison, Silurian System, p. 18; Geol. Cheltenham, 1834, p. 27; *Ibid.*, Ed. 2, by Buckman and Strickland, p. 58.

† Proc. Cotteswold Club, vol. vi., 1876, p. 349.

‡ Murchison, Geol. Cheltenham, Edit. 2, by Buckman and Strickland, p. 40; F. Smithe and W. C. Lucy, Proc. Cotteswold Club, vol. x. p. 207.

the south of Winchcomb (see Fig. 68), the beds have been seen, and some fossils have been obtained;* but the outcrop is largely concealed by detritus from the hills above. On Burrell Hill, east of Buckland, and near Chipping Campden, the beds were formerly worked, but most of the quarries are now obscured. The outcrop is, however, shown by a bold escarpment.

The Marlstone has been quarried in places north-west of Ashton-under-Hill, where the following section was to be seen:—

| | | Ft. | In. |
|---|---|---|---|
| | Soil, brown loam, &c. | 2 | 0 |
| Middle Lias (Marlstone, &c.) | Pale grey, flaggy and sandy limestones, shelly in places; *Belemnites, Pleuromya, Rhynchonella tetrahedra* | 2 | 0 |
| | Rubbly bed of calcareous sandstone having the appearance of "Broken Beds;" *Belemnites* | 1 | 6 |
| | Hard grey and brown limestone with *Pecten æquivalvis* | 2 | 6 |
| | * * * | | |
| | Ferruginous and calcareous brown sandstone. | | |
| | Flaggy calcareous sandstones. | | |
| | Sandy beds, loams, and clays (as at Ebrington). | | |

The Marlstone is used for rough walling and road-metal.

The lower beds were exposed in a lane-cutting north-west of the village. There the lower rubbly beds of Marlstone (above the Ferruginous sandstone) yielded *Ammonites spinatus, Belemnites, Gryphæa gigantea, Pecten æquivalvis, Avicula, Rhynchonella tetrahedra*, &c.

A section of the lower beds of the Middle Lias was exposed in the deep banks of a lane east of Ebrington, leading to Foxcote Farm: it was as follows:—

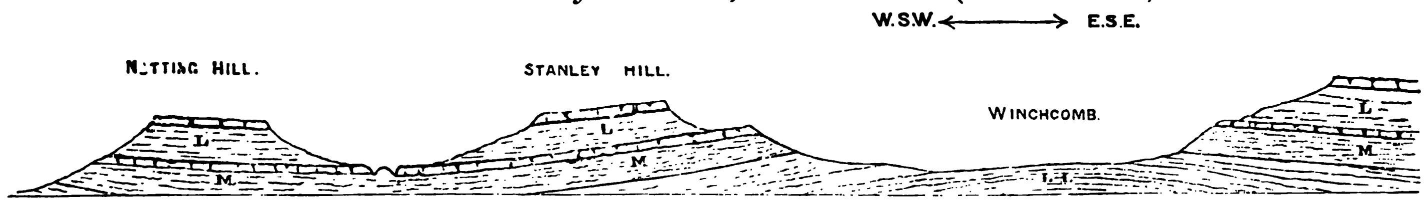
| | | Ft. | In. |
|---|---|---|---|
| Middle Lias. | Yellow micaceous sands | 4 | 0 |
| | Flaggy calcareous and very micaceous sandstone; *Avicula inæquivalvis, Pleuromya* | 2 | 0 |
| | Micaceous sands with *Pholadomya, Pleuromya, Modiola*, more or less fragile - about | 20 | 0 |
| | Flaggy micaceous and calcareous sandstone, impersistent or locally hardened | 1 | 0 |
| | Micaceous sands | 6 | 0 |
| | (Spring thrown out by clays.) | | |

The Marlstone has been quarried at various points around Ebrington Hill, and Mr. Howell notes that a small outlier of this rock occurs at Meon Hill, to the north-east of Mickleton. He states that on the eastern escarpment, between Chipping Campden and Stow-on-the-Wold, the Rock-bed becomes gradually thinner, and the escarpment gradually disappears.† The rock was quarried at Cadley Hill, south-west of Aston Magna; further south near Stow-on-the-Wold, the beds resemble those seen

* See Hull, Geol. Cheltenham, p. 23.
† *Ibid*., p. 19.

FIG. 68.

*Section across the Vale of Winchcomb, Gloucestershire.* (Prof. E. HULL.)




I. Inferior Oolite. L. Upper Lias. M. Middle Lias, with Rock-bed at top. LL. Lower Lias clays.

(The thin representatives of the Midford Sands, between the Inferior Oolite and Upper Lias, are not distinguished.)

near Stroud, the section noted by Prof. Hull, between Mangersbury and Oddington, being as follows* :—

| | | Ft. | In. |
|---|---|---|---|
| Upper Lias | - - - - - - - | 25 | 0 |
| Middle Lias. | Band of ironstone - - - - - | 0 | 6 |
| | Four beds of calcareous sandstone with partings of clay and shale - - - | 16 | |
| | Sand and sandy shale - - - | about 25 | |

The band of ironstone was said to be filled with specimens of *Ammonites annulatus* [ ? *A. Holandrei*]; and, as remarked by Prof. Hull, it is very constant at the top of the Marlstone all over the neighbourhood. He noticed it at Daylesford, and south of Little Milton, and again at Dean near Chadlington. Probably it represents the "Transition Bed" of Northamptonshire.

Towards Upper Slaughter the Middle Lias is much concealed by tumbled masses of Inferior Oolite. Further south, along the borders of the Windrush valley, the beds are rarely exposed, and no sections have been recorded. In company with Mr. W. Topley, I saw traces of the Rock-bed, with *Rhynchonella tetrahedra*, north of Dodd's Mill, near Rissington; but in this area, judging from the evidence of the Burford boring (see pp. 158, 221), and the absence of quarries, the Rock-bed is probably but a few feet in thickness; while the lower sandy shales of the Middle Lias may not exceed 50 feet. Stiff clay with *Ammonites margaritatus* may occur below, as at Deddington.

* Geol. Cheltenham, p. 20.

# CHAPTER VIII.

## MIDDLE LIAS—(*continued*).

### LOCAL DETAILS.

*Oxfordshire, Northamptonshire, and Warwickshire.*

PROCEEDING along the Windrush valley into Oxfordshire we find an inlier of Middle Lias along the borders of the Taynton brook; and this points to some undulations accompanied by faulting of the strata.

Prof. Hull observes that in a quarry south of Daylesford, the Marlstone contains pebbles of slate and sandstone; at Tangley, north of Taynton, the higher beds of the Middle Lias are represented by ferruginous sandstone with *Belemnites*, 10 to 20 feet thick; and at Milton Field, S.W. of Shipton-under-Wychwood, there is about 24 feet of Marlstone, brown sandstone, and sandy shale, resting on clays.* At Ascott-under-Wychwood, the upper beds of the Middle Lias were shown to a depth of 10 feet.

South of Chadlington, to the west of Calsham Bridge, the Marlstone was proved by Mr. F. A. Bather to underlie 40 feet of Upper Lias. Prof. Hull remarks that at West End, near Chadlington, a bed of blue clay immediately underlies the Rock-bed; while near Fawler it is underlaid by sands, with balls of concretionary iron-ore in the top bed. In the railway-cuttings between Fawler and Charlbury the Marlstone was nearly 10 feet thick.†

In the valley of the Evenlode at Fawler, west of Stonesfield, the Marlstone has proved sufficiently rich in iron-ore to have been worked with profit. According to Prof. Hull, the average thickness of the bed is 6 feet, and it no doubt extends in a north-easterly direction to the neighbourhood of Adderbury and King's Sutton. Northwards "at Enstone the ore crops out in the valley, and as far as appearance is to be relied upon, there seems little difference between its qualities there and at the Evenlode valley."‡ Westwards of Ascott the beds although "highly ferruginous" in places, are for the most part sandy in character; and even west of Charlbury the rock-bed is not so ferruginous as to the east, and its thickness is less.

The sections at Fawler showed, beneath the Upper Lias, about 10 feet of oolitic ironstone, reddish-brown with greenish portions towards the base, with here and there clusters of *Rhynchonella tetrahedra* and *Terebratula punctata*. Beneath the Marlstone, about 11 feet of sands, and then blue clay with *Ammonites margaritatus* in the upper part (as before mentioned, p. 158) were reached.§

* Hull, Geol. Cheltenham, pp. 20–23.
† Geol. Woodstock, p. 10.
‡ See Hull, Geol. Woodstock, pp. 10, 11.
§ F. A. Bather, Quart. Journ. Geol. Soc., vol. xlii. p. 144; see also Hull, Geologist, vol. iii. p. 304.

A boring at Burford Signett penetrated the Middle Lias, which appeared to be about 100 feet thick, (See p. 158.) The strata assigned to this formation, were mainly clays, the Rock-bed being no more than 3 ft. 6 in. thick. As the clays of the Middle Lias merge downwards into those of Lower Lias, the thickness given is approximate.

Proceeding northwards the Marlstone has been extensively quarried for building-stone at Chastleton, where it is 12 feet thick and forms "a bold promontory."* The details of the beds in this neighbourhood, were afforded by a well sunk at Kingham Hill (about 630 feet above ordnance datum) in 1880, by Mr. W. Taylor. They were as follows:—

| | | Ft. | In. |
|---|---|---|---|
| | Made ground | 2 | 0 |
| Upper Lias | Clay | 47 | 0 |
| Transition Bed ? | Greenish-drab clay full of fossils | 0 | 9 |
| | Hard shaly clay | 1 | 0 |
| Middle Lias. | Soft red rock | 3 | 3 |
| | Hard do. | 16 | 0 |
| | Grey loamy sands | 9 | 0 |
| | Soft red rock | 15 | 0 |
| | Clayey sand with concretionary masses of sandy limestone | 12 | 0 |
| | Sandy clay | 9 | 0 |
| | Blue clay | 5 | 0 |
| | | 120 | 0 |

During the construction of the tunnel of the Banbury and Cheltenham railway north of Chipping Norton, there were opened up good sections of the Middle Lias, and the beds were noted by Mr. Beesley as follows:—

| | | | Ft. In. |
|---|---|---|---|
| | Upper Lias clay | | 10 0 |
| Middle Lias. | Zone of *Ammonites spinatus* | Brown sandy marlstone | 11 0 |
| | Zone of *Ammonites margaritatus.* | Shale | 5 6 |
| | | Bluish-grey siliceous marlstone (with a band of Serpulæ, *Ditrupa circinata*, in middle) | 2 0 |
| | | Shale | 4 0 |
| | | Blue siliceous marlstone | 2 6 to 4 6 |
| | Blue shales. | | |

From information given by Mr. J. A. Moseley, the resident engineer, Mr. Beesley ascertained that the beds roll over within the hill through which the tunnel was carried, so that in the middle, the lower band of "marlstone" is above the roof, and the railway is excavated in the *Capricornus*-clays below. Few fossils were procured from the Marlstone.

From the hard bands of Middle Lias below, which consist of micaceous and calcareous sandstone with pyritic concretions, and from the shales (which belong partly to the zone of *A. margaritatus* and partly to that of *A. capricornus*), many fossils were collected by Messrs. J. Windoes, E. A. Walford, T. J. Slatter, and

* Hull, Geol. Cheltenham, p. 20.

T. Beesley. Especially fine specimens of *Cypricardia intermedia*, *Cardium truncatum*, together with *A. margaritatus*, *A. nitescens*, *Arca Stricklandi*, *Gryphæa gigantea*, and *Avicula inæquivalvis*, were procured from the hard bands. It was not possible to separate the specimens obtained from the zones of *A. margaritatus* and *A. capricornus*, and Mr Beesley has given a joint list of species obtained from them.* (See p. 158.)

The "Brown Rock," as the Marlstone Rock-bed is sometimes called, is perhaps nowhere better developed than in the country around Banbury. It covers an extensive area to the north-west, forming a plateau that rises gradually from about 500 feet at Banbury to the escarpment of Edge Hill 710 feet high, and this area is intersected by several deep valleys. The high roads are broad, with grassy margins, the hedgerows are well timbered, while the ploughed fields display a rich brown soil. As remarked by Mr. Beesley, the disintegration of its friable stone has produced the rich red land, so well adapted for wheat-growing, which Arthur Young has called the glory of Oxfordshire.† He adds that some of the beds yield nodules rich in phosphates, which doubtless contribute largely to the fertility of the soil.

The rock is usually worked to a depth of from 5 to 14 feet. Its thickness at Banbury is estimated at 12 feet by Mr. Beesley, and it may be seen south-west of the town, north of Spring Cottage, where there is a deep excavation regarded as a natural cavern. The rock too has been quarried further north, and again near Drayton. Its thickness at Hornton must be about 30 feet, and at Swerford 20 feet. It is exposed at Great Tew, in road-cuttings at Broughton, west of Bloxham (see p. 269), and again east of Deddington.

The Marlstone consists of more or less ferruginous and sandy limestone, the amount of sandy and calcareous matter being very variable. It is blue or greenish in colour where least exposed to the action of the weather, but otherwise presents various shades of brown. It is separated by partings of sandy loam or clay. The ferruginous matter, often of a concretionary nature and sometimes iron-shot, varies considerably in different places, so that while at Adderbury and Kings Sutton the rock has become sufficiently charged with iron-ore to yield from 18 to 34 per cent. of metal, at Hornton and Edge Hill the stone furnishes a tough earthy limestone employed for building and paving. The greenish and brown varieties, often intermixed in edifices, form pleasing contrasts. Houses and walls in and around Banbury are largely constructed of the Marlstone, mostly of the brown rock which in appearance reminds one of the carstone or "gingerbread" stone of Hunstanton. In some places concretionary nodules impart a conglomeratic aspect to the stone. I am informed by Mr. E. A. Walford that a bed of this nature occurs at the base of the Rock-

* Proc. Geol. Assoc. vol. v. p. 181.

† Proc. Warwicksh. Field Club, 1872, p. 16; Young, Agriculture of Oxfordshire, 1809, p. 5.

bed at Hook (or Hog's) Norton, where the overlying portions of the Marlstone have recently been worked (east of the railway-station) for ironstone. (See p. 304.)

The most abundant fossils in the Marlstone are *Terebratula punctata* and *Rhynchonella tetrahedra*, which occur in clusters at various horizons: but often the stone is free from fossils and to this absence Hornton owes much of the excellence of its stone. *Waldheimia resupinata, W. Moorei, W. indentata*, and *W. perforata* are also found. Belemnites are not uncommon, but Ammonites are very rare, so far as my experience goes, for I did not obtain a single specimen of the characteristic *A. spinatus*, which Mr. Beesley says is not uncommon. *Cardinia concinna, Pecten æquivalvis, P. lunularis, Modiola, Lima, Ostrea sportella, Pleuromya*, and *Pentacrinus*, together with drift-wood and Saurian bones are also met with. Mr. Beesley states that *Ammonites margaritatus* sometimes occurs. Altogether he obtained about 80 species of fossils from the beds.* Remains of Polyzoa (*Tubulipora inconstans* and *Stomatopora*), and also of a Sponge (*Leucandra Walfordi*) have been discovered by Mr. E. A. Walford.†

Portions of the Middle Lias according to Strickland, were well exhibited in a cutting in Steeple Aston parish (G.W. Railway). He mentions that "Two strata of stone are here exhibited, the upper about 2, the lower 3 or 4 feet thick, separated by a bed of bluish sandy clay. The lower bed consists of enormous roundish flattened concretions 10 or 12 feet in diameter, and exceedingly hard. Many hundreds of tons of this rock have been removed by blasting, and are now lying on the sides of the railway."‡

These beds are probably below the Marlstone, for Prof. Hull notes that the rock-bed at Lower Heyford is essentially an iron-ore, and rests on beds of sand, with bands of siliceous limestone, together about 20 feet thick. At Steeple Aston the ore, as he remarks, has been smelted, and from the analysis, there appears to be little difference in its quality from that of the bed at Fawler.§ At Rousham also the Marlstone is highly ferruginous. Its thickness in this area is from 5 to 8 feet.

The Marlstone has been extensively quarried about half a mile east of Adderbury church, to the south of the high road; and here the beds shown were as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Upper Lias. | Brown and dark bluish-grey clay with interrupted band of pale grey and pinkish earthy limestone; *Ammonites serpentinus, A. communis, Belmnites* | 4 | 6 |
| Middle Lias (Marlstone). | Brown and dark greenish Marlstone—fissile in places, with *A. acutus, A. communis, A. annulatus, A. Eseri, Rhynchonella tetrahedra, Terebratula punctata*, and large Belemnites in top bed. *R. tetrahedra* and *Belemnites* here and there lower down - - about | 9 | 0 |

* Proc. Warwickshire Field Club, 1872, p. 20.

† Quart. Journ. Geol. Soc., vol. xliii. p. 632; and G. J. Hinde, Ann. Nat. Hist., ser. 6, vol. iv., p. 352.

‡ Strickland, Memoirs, p. 184.

§ Geol. Woodstock, pp. 9, 10. See also J. Phillips, Quart. Journ. Geol. Soc., vol. xvi., p. 116, and Geol. Oxford, p. 115.

The beds are much shattered in places, and the joints, which present a series of miniature step-like faults, are filled with clay, derived from the Upper Lias. The Transition Bed (see p. 228) is not so distinctly shown as elsewhere in the neighbourhood, being probably welded on to the Marlstone as it is at Tilton in Leicestershire.

The railway-cutting north of the high road, showed the lower beds beneath about 9 feet of the Marlstone :—

| | | Ft. | In. |
|---|---|---|---|
| Middle Lias. | 3. Micaceous sandy and ferruginous beds | 7 | 6 |
| | 2. Hard rock with nodules of grey sandy rock at base. Large *Belemnites*, *Pecten* near to *dentatus*, *Modiola*, *Pleuromya*, *Rhynchonella*, Saurian Bones (*Ichthyosaurus*) about | 3 | 0 |
| | 1. Yellowish and bluish sandy loam | [4 | 0] |

This section was also noted by Mr. Beesley, who recorded *Ammonites spinatus* from the Marlstone, and *A. margaritatus* from the lower rock (= bed No. 2).*

Large specimens of *Pecten æquivalvis* 7 or 8 inches across have been found in the Marlstone of Adderbury, and also near Chacombe (Chalcombe).

In a trial-pit in the park at Adderbury, the following beds were penetrated† :—

| | | Ft. | In. |
|---|---|---|---|
| Middle Lias. | Ferruginous marlstone | 11 | 0 |
| | Shale | 3 | 0 |
| | Grey shelly limestone | 1 | 0 |
| | Rusty concretionary bed ("ochre") | 0 | 6 |
| | Shale | 12 | 0 |
| | Pale blue argillaceous limestone with concretions, and a concretionary bed below | 1 | 0 |

Mr. Beesley remarked that the lowest bed here corresponds to the calcareous sandstone of Twyford. He adds, "The same bed was formerly worked for road metal at Warkworth, one and a half miles east of Banbury. It was there a blue marly sandstone, four feet thick, and full of fossils. The same bed and the underlying marly clays may be well seen in a brickyard south of Deddington. The 'Cross' at Banbury stands upon this stone."

The lower beds of the Middle Lias were also exposed in the railway-cutting west of the high-road between Adderbury and Aynho. The section described by Mr. Beesley was as follows‡ :—

| | | Ft. | In. |
|---|---|---|---|
| Middle Lias | Rubble of Marlstone. | | |
| | Siliceous marlstone in concretionary blocks, with much calcite | 2 | 0 |
| | Sandy shale | 9 | 0 |
| | Concretionary blocks. | | |
| | Dark blue laminated clays. | | |

The lowest beds of blue clay, of which only a few feet were seen, were referred to the zone of *A. capricornus* by Mr. Beesley, but it is questionable (in the absence of fossil evidence) whether that zone was reached.

* Proc. Geol. Assoc., vol. v. p. 167.
† T. Beesley, Proc. Warwickshire Field Club, 1872, p. 15.
‡ Proc. Geol. Assoc., vol. v. p. 167.

At the old ironstone-works at King's Sutton, situated south-west of the railway-station, the section as recorded by Mr. Beesley was as follows:—

| | | Ft. | In. |
|---|---|---|---|
| | Soil, very sandy and ferruginous - - | 2 | 6 |
| Middle Lias | Marlstone, with beds yielding *Rhynchonella tetrahedra*, *Waldheimia resupinata*, and *Terebratula punctata* - - - | 4 | 2 |
| | Marlstone with phosphatic concretions - | 1 | 0 |
| | Rusty ferruginous concretions - - | 1 | 8 |
| | Sandy blue marl and grey shale. | | |

The Brickyard at the Wharf, Twyford Lane, west of Twyford Bridge, N.W. of King's Sutton, showed the following section of the lower beds of the Middle Lias:—

| | | Ft. | In. |
|---|---|---|---|
| Middle Lias | Micaceous grey and blue sandy loams - | 5 | 6 |
| | Hard blue micaceous and sandy limestone or calcareous sandstone (like the Starfish-bed of Seatown, Dorset), with irony nodules and in places septaria; *Belemnites*, *Pecten*, *Pleuromya costata*, *Modiola* 2 0 to | 3 | 0 |
| | Blue micaceous clays with small ironstone- and cement-stone nodules; *Ammonites margaritatus* - - - about | 10 | 0 |

Mr. Beesley informed me that the Lower Lias with *Ammonites capricornus*, &c. had been formerly reached in the excavations here.* The fossils enumerated by him indicate beds like those from the Chipping Norton tunnel (see p. 158) at the junction of Middle and Lower Lias. *A. Henleyi* (prob. *striatus*) has also been recorded.

Similar beds of Middle Lias have been exposed at the brick-kiln south of Deddington, where the section was as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Middle Lias | Brown and pale-grey ferruginous and micaceous sands and sandy clays; with indurated calcareous, brown and grey shelly sandstone in places; one layer at the base - | 10 | 0 |
| | Blue sandy micaceous clay, passing down into blue micaceous and slightly calcareous clay, with cement-stones and septarian limestones - - about | 20 | 0 |

Large and small Belemnites, *B. cylindricus*, *B. elongatus*, and *B. vulgaris*, *Ammonites margaritatus*, *Cypricardia*, *Ostrea*, *Gryphæa*, *Pecten æquivalvis*, *Plicatula spinosa*, some of them pyritic, occur in these beds. *Ditrupa circinata* is recorded from the calcareous sandstone at Twyford and Deddington, and from a similar bed at Chipping Norton, by Mr. E. A. Walford.

The sands and sandstones below the Rock-bed, were to be seen on the Banbury road, a little west of Middleton Cheney.†

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* Proc. Geol. Assoc., vol. iii. p. 197.
† Green, Geol. Banbury, p. 6.

The Transition-bed (with *Ammonites acutus*) has not been particularly noted south of Banbury. It is probably present in the following section taken in a quarry north-west of Broughton :—

| | | Ft. | In. |
|---|---|---|---|
| Upper Lias. | Brown clay - - - about | 2 | 6 |
| | Ferruginous earthy clay and stone. *Ammonites communis, A. bifrons* - - | 1 | 0 |
| | Purplish and grey clay. *Belemnites* - - | 1 | 0 |
| | Mottled earthy and ferruginous limestone. *Ammonites* and *Belemnites* - - | 0 | 8 |
| Transition Bed. | Ferruginous grey and yellowish marly bed. *A. communis* - - - - - | 0 | 8 |
| Middle Lias. (Marlstone.) | Hard brown and greenish earthy limestone. *Belemnites* abundant. More or less ferruginous sandy limestones, and ironstone-beds - - about | 10 | 0 |

The brickyard east of Easington, south of Banbury, showed the lower beds of Middle Lias as follows :—

| | | Ft. | In. |
|---|---|---|---|
| Middle Lias. | Fissile calcareous sandstone in large concretionary masses, very micaceous 0 6 to | 1 | 6 |
| | Pale grey and brown micaceous sandy clays, with paler lenticular clayey masses. Obscure casts of *Avicula, Cardium*, &c. - | 20 | 0 |

These beds are exposed in the cutting of the road leading from Banbury towards Broughton.

Lower beds are exposed in the brickyard by the Canal to the east of the above, as follows :—

| | | Ft. | In. |
|---|---|---|---|
| Middle Lias - | Brown micaceous sandy loam - about | 10 | 0 |
| Lower Lias. | Blue sandy and micaceous shaly clay, with hard brown earthy and ferruginous nodules - - - - about | 10 | 0 |

I found one specimen of *Ammonites capricornus*, and it is probable that the beds represent the base of the zone of *A. margaritatus* and the top of that of *A. capricornus*. This is confirmed by the list given by Mr. T. Beesley, where fossils characteristic of the two zones are given; but they are not separated by him. A separate list is however given of fossils from the shales immediately below the Marlstone of Banbury, in which the occurrence of *Ammonites Engelhardti* with *A. margaritatus* is noteworthy.* (See also pp. 216, 231.)

The most important quarries in the Marlstone of this district are those at Hornton, about a mile north-west of the church. There are several quarries here, from 20 to 25 feet deep. These show the following beds :—

| | | Ft. | In. |
|---|---|---|---|
| Middle Lias (Marlstone). | Brown loamy and rubbly soil - 3 0 to | 5 | 0 |
| | Brown (and blue-hearted) sandy ironstone more or less rubbly or thin bedded - | 7 | 0 |
| | Brown bluish and greenish, slightly calcareous, sandy and ferruginous stone, in more or less massive beds - - - about | 9 | 0 |

* Proc. Warwickshire Field Club, 1872, pp. 14, 15.

At another quarry a little further north the beds are opened to a depth of 25 feet—the lower beds for 7 or 8 feet being the best. At this locality a well was sunk 33 feet, water standing at a depth of 3 feet.

*Rhynchonella tetrahedra* occurs in clusters here and there in the stone-beds, *Terebratula punctata* is also met with, as well as *Belemnites*, but the stone is usually free from shells.

The lower beds of the Middle Lias (zone of *Ammonites margaritatus*) were shown in a deep cutting in Hornton Lane, which I visited in company with Mr. E. A. Walford and Mr. S. Stutterd. The section was as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Middle Lias | Brown stone with much ferruginous matter, and pebbly layer at base. | | |
| | Shelly marlstone - - - | 2 | 0 |
| | Micaceous sandy shale - - - | 12 | 0 |
| | Hard flaggy, micaceous and calcareous sandstone - - - - - - | 1 | 2 |
| | Micaceous sandy shale - - - | 15 | 0 |
| | Shelly stone, 2 or 3 beds, *Cardinia* - - | 2 | 0 |
| | Micaceous sandy shale - - about | 25 | 0 |

Mr. Walford has also noted an exposure of the lower clayey beds with *Cypricardia cucullata*, at a brickyard at Arlescote, north-east of Edge Hill.

The escarpment of the Middle Lias at Edge Hill, as remarked by A. Beesley, has the appearance of a steep ridge with a remarkably well-defined edge, when seen from the Warwickshire vale beneath. The outline of the figure of a horse, said to have been originally cut during the fifteenth century, in the red loam on the side of the hill, near the old inn called the Sun Rising, and not far from Edgehill House, gave the name of the Vale of Red Horse to the plain below.* Conybeare writing in 1822 says, "The original figure has been destroyed by recent enclosures; and modern art has only replaced it by a miserable colt."†

South and south-east of Edgehill Tower and Ratley Grange, there are several large quarries where the stone, generally termed the Hornton Stone, is obtained. The strata are worked to a depth of about 25 feet: the uppermost beds are broken up near the surface by the action of rain and frosts. The following section was shown in one of the quarries:—

| | | Ft. | In. |
|---|---|---|---|
| | Traces of Upper Lias with *Ammonites serpentinus*, in clay in the joints of the Marlstone. | | |
| Middle Lias. | False-bedded blue and brown earthy limestone, used for road-metal, although not so much in demand now as formerly - | 10 | 0 |
| | Thin bedded blue-hearted marlstone very hard. "Rag course" used for paving - | 4 | 0 |
| | Rubbly stone - - - - - | 1 | 0 |
| | Thick bed of marlstone much fissured, used for walls, and known as "Hawkins Bed" | 3 | 0 |
| | Building stone—best stone - - - | 7 | 0 |

* History of Banbury, 1842, p. 310. See also Walford, Edge Hill: The Battle, &c. 8vo. Banbury, 1886.

† Outlines of the Geol. Eng. and Wales, p. 249.

On Burton Dassett Hill there are large quarries in the Marlstone. On Bitham Hill which rises to a height of about 690 feet, the rock is very ferruginous; and siliceous iron-ore also occurs in the outlier of Northampton Sands at this locality.*

North-east of Banbury, at Chipping Warden, Aston-le-Wall, and other localities, in Oxfordshire, Northamptonshire, and Leicestershire, a remarkably fossiliferous bed occurs at the junction of the Middle and Upper Lias. This was termed the Passage-bed in 1872 by Mr. T. Beesley,† who first found in it *Ammonites acutus*, a species described by Prof. Tate.‡

In 1878 Mr. E. A. Walford, applying the term "Transition-bed," gave detailed accounts of the sections, and a long list of species obtained from the bed; and subsequently it has been examined and described in many places by Mr. Beeby Thompson, Mr. E. Wilson, and Mr. W. D. Crick.

The bed consists of grey friable marl and marly limestone from 1 to 9 in. thick, and from the local abundance of *Ammonites acutus* it might have been termed the zone of that fossil, although the species occurs both above and below the particular horizon.

Mr. Walford observes, "We may regard it as a Transition bed from the Middle to the Upper Lias, though for purposes of classification, taking Tate and Blake's divisions as our standard, from a preponderance of medio-liassic forms it may be placed as the uppermost member of the Middle Lias, and hence perhaps synchronous with Tate and Blake's zone of *Ammonites annulatus*."§ As the zone of *A. annulatus* is generally regarded as the base of the Upper Lias, we should most properly group the Transition Bed with that formation. It is, however, more convenient to consider it with the Middle Lias.

Its comparative insignificance is quite consistent with the notion that to some extent, when present in a friable condition, it may be due to the decomposition of the underlying rock, while the frequent abundance of organic remains may in this, as in other cases, be the result of some pause in the deposition of sediment.

The following section, seen in a pit about a mile north of the church at Chipping Warden, gives the general characters of the beds. I was conducted to the spot by Mr. Walford who has given the following description‖ :—

| | | Ft. | In. |
|---|---|---|---|
| | Soil - - - - - - | 1 | 6 |
| Upper Lias. | Grey clay with interrupted band of white limestone, with *Ammonites crassus*, &c. - | 2 | 2 |
| | Limestone in two bands (Fish-bed), with Fish-remains, *Euomphalus* (?) *minutus*, &c. | 0 | 3 |

* Hull, Explanation of Hor. Section, Sheets 71 and 72, p. 5.

† Proc. Warwickshire Field Club for 1872, 1873, pp. 18, 23.

‡ Geol. Mag. 1875, p. 204.

§ Proc. Warwickshire Field Club for 1878, 1879; and Journ. Northampt. Nat. Hist. Soc., 1883, p. 296. See also Beesley, Proc. Geol. Assoc., vol. v. p. 167.

‖ On some Middle and Upper Lias Beds in the Neighbourhood of Banbury, Proc. Warwicksh. Nat. Club, 1878, Reprinted Banbury, 1879, p. 6; see also Notes on some Polyzoa from the Lias, Quart. Journ. Geol. Soc., vol. xliii. p. 632; and B. Thompson, Rep. Brit. Assoc. for 1891, p. 334.

| | | Ft. | In. |
|---|---|---|---|
| Transition Bed. | Grey friable and fossiliferous marl, with *Am. acutus*, *A. Holandrei*, &c. - - | 0 | 6 |
| Middle Lias (Marlstone). | Ferruginous limestone (as below) - - | 0 | 3 |
| | Sandy marl - - - - - - | 0 | 3 |
| | Ferruginous limestone. | | |

The following are among the species recorded from the Transition Bed, by Messrs. Beesley, Walford, and Beeby Thompson:—

Hybodus.
Ammonites acutus.
—— annulatus.*
—— cæcilia.
—— communis.
—— crassus.
—— Holandrei.*
Belemnites cylindricus.
—— tripartitus.
Actæonina ilminsterensis
Amberleya gaudryana.
Ataphrus (Turbo) bullatus.
Bourguetia (Phasianella) turbinata.
Cerithinella confusum.
Cerithium ferreum.
—— liassicum.
Cryptænia expansa.
—— consobrina.
—— solarioides.
Pitonnillus linctus.
Pleurotomaria helicinoides.
—— rustica.
Trochus Ægion.
—— rotulus.
Trochus pethertonensis.
Turbo cyclostoma.
Turritella Dunkeri.
Dentalium elongatum.
—— liassicum.
Astarte subtetragona.
—— Voltzi.
Cardium truncatum.
Cucullæa hettangiensis.
—— Münsteri.
Cypricardia cucullata.
Lima eucharis.
—— punctata.
Macrodon Buckmani.
Ostrea sportella.
Pecten dentatus (var. of æquivalvis).
—— textorius.
Plicatula spinosa.
Unicardium subglobosum.
Rhynchonella tetrahedra.
Waldheimia resupinata.
Tubulipora inconstans.
Montlivaltia tuberculata.

Mr. Walford has compared this Transition Bed with the Marlstone *Pleurotomaria*-bed on the Dorsetshire coast,† and there can be no doubt of the beds being on the same horizon, while the overlying basement-beds of the Upper Lias exhibit a close correspondence throughout the country. Hence this fossiliferous horizon may occur at any locality at the junction of the Middle and Upper Lias, although as in the case of other fossil-beds, a rich harvest of fossils is only here and there preserved.

Deposits yielding many Liassic Gasteropods have been noticed by C. Moore in South Wales and on the Mendip Hills,‡ but these appear to be of different ages, although some of them have yielded species found in the Transition Bed. They have been compared with deposits discovered by Deslongchamps,§ at Fontaine-étoupe-Four and other places in Normandy, where the fossiliferous beds occur in rifts and hollows of the Silurian rocks. In that country, as in this, accumulations of different Liassic stages are preserved, some being evidently equivalent in age to

* Considerable difficulty appears to exist in separating the forms identified as Am. annulatus and A. Holandrei, in the district around Banbury. (See p. 250.)
† Journ. Northamptonshire Nat. Hist. Soc. 1883, pp. 296, &c.
‡ Quart. Journ. Geol. Soc., vol. xxiii. pp. 475, &c.
§ Mémoire sur la Couche à Leptæna du Lias, 1859.

the Transition Bed. Mr. Walford also points out that in Bavaria Dr. Stoliczka has recognized a similar fauna, and, from the Hierlatz and Adnether beds, has obtained many species of Liassic Mollusca.

At Coton, north-west of Chacombe, the Marlstone is quarried for road-metal. It has yielded in this neighbourhood fine specimens of *Pecten æquivalvis,* also *Pleuromya costata,* and *Cardium truncatum.* The lower beds of the rock are in places of a "slaty" nature, and I was informed by the Rev. W. A. Ayton that the porch in Chacombe Church was roofed with this material.

At Thenford the Marlstone was formerly dug for building-stone. The beds have been opened up to a depth of 12 feet, with the Transition-bed and Upper Lias on top. (See p. 274.)

Many other quarries have been opened up in the Marlstone and the basement-beds of the Upper Lias. Most of these have been described by Mr. Beeby Thompson.* In addition to the localities before mentioned, sections have been noted at Wardington,† Byfield, Hellidon, Kingbrook north of Preston Capes,‡ Badby, Newnham, W.N.W. of Stowe-nine-churches, and nearer Northampton at Rothersthorpe, and Milton Malsor (or Middleton).

In a boring at the Kettering road, Northampton, the thickness of the stone-beds was proved to be 21 feet;§ and of the underlying Middle and Lower Lias clays, 546 feet. Similar beds were proved at the London and North-Western Railway-station at Northampton. At Kingsthorpe, 760 feet of Upper, Middle, and Lower Lias were proved. (See p. 278.) At Harrington Dale, near Orton, west of Kettering, the Marlstone was but 6 feet thick, the underlying Middle Lias clays about 112 feet, and Lower Lias 500 feet; and between Kettering and Weekley a boring proved 18 feet of rock, beneath 44 feet of Upper Lias clay.

With regard to the southerly and south-easterly extent of the Middle Lias we have but little evidence. The boring at Wytham, near Oxford, probably passed through beds of this age at depths of from 462 to about 500 feet: but the record is not sufficiently definite for precise statements. A boring at Stratton Audley in Buckinghamshire, commenced in the Cornbrash, was carried to a depth of 243 feet, finding water, probably in the Marlstone.‖ Far eastwards at Stony Stratford it was probably reached at a depth of 191 feet; there its thickness appears to be 5 feet 6 inches, and it rested on 18 feet of hard clay with occasional bands of rock. (See p. 277.)

Over much of Northamptonshire, as in Oxfordshire, the boundary between Middle and Lower Lias (on the Geological

* The Middle Lias of Northamptonshire, 1889. See also H. B. Woodward, Explanation of Horizontal Section, Sheet 140, p. 7.

† Conybeare, who was at one time Curate of Wardington, has given a good account of the physical features of this district. Geol. Eng. and Wales, 1822, pp. 246, &c.

‡ H. B. Woodward, Explanation of Horizontal Section, Sheet 140, p. 7.

§ H. J Eunson, Quart. Journ. Geol. Soc., vol. xl. p. 484; Journ. Northampton Nat. Hist. Soc., vol. ii., p. 29, vol. iv. p. 57; and Thompson, Mid. Lias, Northampt., p. 48.

‖ Green, Geol. Banbury, p. 28.

Survey Map) has been generally taken on top of the stiff blue clays, that belong in part to the zone of *Ammonites margaritatus*. Thus near Welton Station, clays, yielding *Ammonites margaritatus*, *A. Engelhardti*, and also Lower Lias species, have been dug in a brick-yard. (See pp. 166, 226.)

"The exact boundary between the Lower Lias and the Marlstone, north and east of Weedon [Beck], is uncertain, the ground being thickly covered with drift."*

Outliers of Marlstone occur at Bodington, Napton Hill, Upper Shuckburgh, Welton, Watford Gap, and Barby Hill.†

Marlstone (hard calcareous sandy and ferruginous rock) has been quarried near Brockhall and Whilton, and the rock has been exposed near Long Buckby and Watford. The lower beds, consisting of sandy and ferruginous shales and clays, with hard concretions, have been opened up at Murcot, near Long Buckby, and at Winwick. As remarked by Mr. Aveline, inliers of Marlstone may occur to the south-east, near Cottesbrook, in the valleys of the Stowe and Callender brooks, where some rock-beds were observed during the progress of the Geological Survey, but the beds occupy too small a space to be clearly represented on the map.‡

North-east of Elkington the Marlstone appears to be represented by soft beds of sandstone and sandy marl, while in the neighbourhood of Welford the beds are concealed by Drift.

### *Leicestershire, Rutlandshire, and Lincolnshire.*

The poor development of the Marlstone (as a rock-bed) in parts of this region, was shown in cuttings of the railway between Northampton and Market Harborough, near Oxenden Magna, where according to Mr. Aveline the beds are represented by sandy shales and a few concretionary beds; nevertheless the beds form a striking escarpment at East Farndon and the Holthorpe Hills, north of Sibbertoft. In the outlier at Gumley no hard beds were seen, soft ferruginous sand being observed beneath a covering of Drift.§

The lower beds of the Middle Lias were shown in a brick-yard at Little Bowden, south of Market Harborough station:—

| | | Ft. | In. |
|---|---|---|---|
| Middle Lias. | Slightly micaceous and sandy shales, with, at base, ochreous nodules with *Ammonites margaritatus* and Gasteropoda - - - - - | 5 | 0 |
| Lower Lias. | Grey shales passing down into blue clay, with *Ammonites capricornus* - - - | 55 | 0 |

* Aveline and Trench, Geol. part of Northamptonshire, p. 5. In this work, fossils from the Middle and Upper Lias are not separated.

† Rep. Rugby School Nat. Hist. Soc., for 1869, p. 27, and 1878, p. 44.

‡ Geol. parts of Northamptonshire and Warwickshire, p. 6.

§ Aveline and Howell, Geol. of part of Leicestershire, p. 5.

The local attenuation of the Middle Lias in this area is borne out by the observations of Prof. Judd, who in describing the beds in Rutlandshire and bordering tracts, remarks that while 150 feet thick in the northern part of that area, they are reduced to less than half that amount in the southern part.*

The divisions observed by Prof. Judd in Rutlandshire and adjoining tracts, may be summarized as follows† :—

5. *Marlstone Rock-Bed.*—Limestone, more or less ferruginous, and passing in places into a good ironstone. The rock is often crowded with fossils, its mass being made up of fragments of Crinoids, spines of Echinoderms, Serpulæ, and fragments of shells, while certain beds in it (locally known to quarrymen as "jacks") consist of an agglomeration of shells of *Rhynchonella tetrahedra* and *Terebratula punctata*, usually filled with finely crystallized calcspar. *Belemnites paxillosus* and *B. elongatus* are extremely abundant in the Rock-bed, and serve to distinguish it from the Northampton Sand, which often resembles it in mineralogical characters, but in which *Belemnites* are exceedingly rare. *Ammonites* are not abundant in the Rock-bed in this district, but at some points, as Edmondthorpe, Loddington and Horninghold, *Ammonites communis*, and *A. annulatus* occur in considerable numbers; *A. spinatus*, and some varieties of *A. margaritatus*, are also found in it, but much more rarely, in this district. Large specimens of *Pecten æquivalvis*, with the highly-characteristic *P. dentatus*, also *Hinnites abjectus*, and *Avicula inæquivalvis*, are among the most abundant forms in the Rock-bed.

The Rock-bed is very variable both in thickness and mineralogical character; it is finely developed in the neighbourhoods of Tilton-on-the-Hill and Somerby, near the former of which places, it is seen to measure 18 feet 6 inches in thickness; towards the east and south, however, it attenuates very rapidly, being only 8 or 9 feet thick about Oakham, 2½ feet at Alexton, 2 feet at Godeby and at Horninghold, and less than 1 foot between Keythorpe and Hallaton. Besides being greatly diminished in thickness, the bed sometimes loses its calcareous character and becomes sandy, in these cases often resembling the other hard beds which occur lower in the Middle Lias. When the junction of the Upper Lias clay and the Rock-bed is seen, the latter often presents the appearance of having suffered erosion before the deposition of the former. Insignificant, however, as the Rock-bed often becomes, there is no certain evidence of its actual disappearance within the area, but in places, its presence being doubtful, it is indicated on the map by broken lines only.

4. Light blue clays, with bands of ironstone-balls of concentric structure, and usually very unfossiliferous. These beds are exposed in some brickyards about Oakham, at Langham, and at Market Harborough. At some places they contain beds of green and brown sand, as near Horninghold.

3. Beds of blue clay with septaria, the latter not unfrequently containing Specular Iron, and weathering to a red colour. They contain many of the fossils recorded from the preceding beds, but less abundantly. They are exposed in Belton, Hallaton, and Cranhoe brickyards.

2. Beds of blue, highly micaceous clay, with large septaria crowded with fossils. There were two brickyards in these beds at Ouston, and between Whissendine and Pickwell. The most abundant species in these beds are *Ammonites margaritatus* (the large typical form), *Belemnites elongatus*, *Cryptænia* (*Helicina*) *expansa*, *Avicula inæquivalvis*, *Hippopodium ponderosum*, *Modiola scalprum* (very abundant), *Cardium truncatum*, *Pleuromya costata*, and *Pentacrinus subangularis*.

1. Soft, yellowish-brown, sandy and micaceous ironstone, crowded with casts of shells, and alternating with light blue clays. These ferruginous bands vary very greatly in number and thickness, and are sometimes nodular. They

* Geol. Rutland, p. 64.

† Geol. Rutland, pp. 64–66.

are especially characterised by the abundance of several small varieties of *Ammonites margaritatus* and *Cardium truncatum*. They were exposed in the Melton and Oakham Canal between Edmondthorpe and Whissendine station, in the hill east of Whissendine station, at Blaston, Loddington, and Deepdale.

The clays of this division pass down into the Lower Lias clays with *Ammonites capricornus*, &c., and (as remarked by Prof. Judd) it is not always easy to separate them, so that their boundary on the map is represented by a broken line.

Referring to the neighbourhood of Neville Holt, Prof. Judd says, "It may be considered by some as open to question whether, at this and some other points, the Marlstone Rock-bed has not been wholly removed by denudation before the deposition of the Upper Lias Clay. The more probable opinion, and that which has been adopted by the Survey, is that the Marlstone Rock-bed is represented in a greatly attenuated and rudimentary condition by the nodular bands which occur at the top of the Middle Lias Series. Indeed, at some points there occurs a transition from the irregular and inconstant nodular bands, to a well defined Rock-bed presenting the characteristic features, both lithological and palæontological, of the highest member of the Middle Lias."*

The thickness of the Rock-bed at Great Bowden is only 2 feet, according to Mr. H. E. Quilter. In this neighbourhood he notes that there is a clear line of demarcation between the Middle and Lower Lias. The Middle Lias clays contain ironstone-nodules, as in the section noticed at Little Bowden, and they are very unfossiliferous, while the Lower Lias clays below, contain nodules with *Ammonites capricornus* and other fossils.†

In a brickyard near Sutton Basset, Prof. Judd noted the following section:—

| | | Ft. | In. |
|---|---|---|---|
| | Soil and Boulder Clay | 3 | 0 |
| | Upper Lias Clay | 2 | 0 |
| Middle Lias. | Rock-bed of the Marlstone | 4 | 0 |
| | Brown clay, containing nodules of ironstone | 3 | 0 |
| | "Skerry," a thin band of ferruginous, micaceous rock, crowded with fossils | 0 | 6 |
| | Laminated, light-blue clay containing much mica; weathering brown near the joint-planes | 8 | 0 |
| | A thin band similar to the Skerry. | | |

Prof. Judd notes also that near Ashley, on the road to Wilbarston, the Rock-bed of the Marlstone is clearly exposed, and is seen to consist of several beds of stone, sometimes of a decidedly calcareous character, and containing peculiar flattened nodules.‡ He states that at the foot of the Hill on which the Neville-Holt ironworks were opened, in a cutting made for the railway-incline, the basement-beds of the Upper Lias were underlaid by the Middle Lias series, as follows§ :—

* Geol. Rutland, p. 75.
† Rep. Leicester Lit. and Phil. Soc. for 1883–84, p. 87.
‡ Geol. Rutland, p. 75.
§ *Ibid.*, pp. 73–77.

| | |
|---|---|
| Middle Lias. | Irregular beds of micaceous and ferruginous sandy rock, full of casts of shells. These form two or three beds of stone, in places more or less calcareous. They do not, however, present the characteristic features of the Rock-bed, but are always of a more or less nodular character. They contain *Belemnites*, usually grouped together in considerable numbers in certain parts of the rock, and also a few rounded pebbles or concretions like those of the Rock-bed. The species of fossils found in these bands were as follows:—<br>Pecten lunularis (large, 5 inches in diameter).<br>Avicula novemcostæ.<br>Cardium truncatum.<br>Leda complanata.<br>Light-coloured clays containing bands of ironstone-nodules (of considerable thickness). |
| Lower Lias. | The lowest beds seen at this point are exposed in the brickyard below, and consist of blue, micaceous clay, containing flattened nodules of clay-ironstone with a few fossils:—<br>Belemnites (fragments).<br>Ammonites capricornus.<br>Leda complanata.<br>Cardium truncatum.<br>Ostrea.<br>Wood. |

On the south side of Slawston Hill the Marlstone is scarcely traceable. The Middle Lias here may be from 60 to 70 feet in thickness. At the north-west end of Slawston outlier, the Rock-bed of the Marlstone presents its usual characters, and consists of a hard calcareous rock containing *Avicula novemcostæ*, *Rhynchonella tetrahedra*, and *Terebratula punctata*. Large masses of carbonate of lime, crystallized in the forms known as "Dog-tooth spar" and "Nail-head Spar," are seen in the rock at this place.

Below the Marlstone there were exposed in the railway-cutting, about 50 feet of blue shales with bands of ferruginous rock, and in the upper portion of the shales *Ammonites margaritatus* has been found.*

Near the bridle-road leading from Keythorpe to Hallaton, and at the point where it crosses the brook, some old pits exhibited the following section, described by Prof. Judd:—

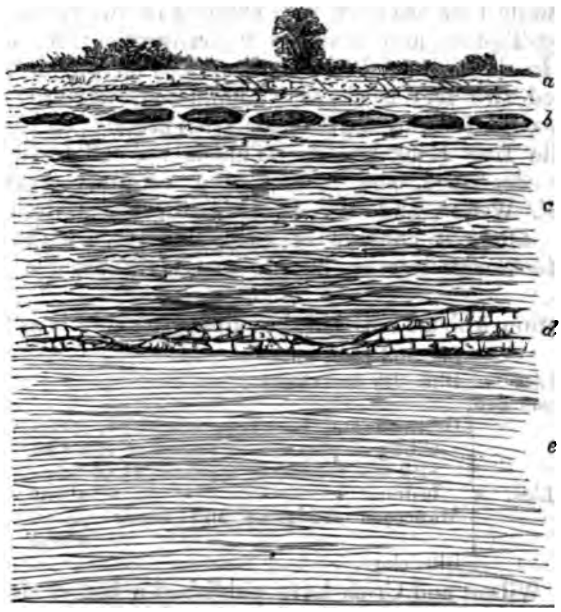
| | | |
|---|---|---|
| Upper Lias. | Laminated shales with traces of the "fish and insect beds" at the top - - | 5 to 6 feet. |
| Middle Lias. | Rock-bed with usual characters, containing numerous *Belemnites*, *Ammonites annulatus*, *Terebratula punctata*, &c. As is often the case with this rock, it here contains numerous rounded pebbles or concretions - - - - | 1 ft. seen. |
| | Light-blue clays passing down into clays with bands and nodules of ferruginous and micaceous rock. | |

The irregular mode of recurrence of the diminutive representative of the Marlstone Rock-bed, is illustrated in the following sketch of a section seen at this point (Fig. 69).

* J. Marriott, Rep. Leicester Lit. and Phil. Soc. for 1883–84, p. 80.

FIG. 69.

*Section between Keythorpe and Hallaton, Leicestershire.*
(Prof. J. W. JUDD.)




a. Soil, &c.
Upper Lias { b. Fish and Insect limestones.
c. Clays.
Middle Lias { d. Marlstone Rock-bed.
e. Clays, &c.

Along their outcrop from Deepdale to beyond Cranhoe, the lower beds of the Middle Lias series are almost wholly unknown, owing to the prevalence of Drift. A brickyard at Belton exposed the clays with *Ammonites margaritatus*, &c.

At Godeby (as Prof. Judd remarks) the Marlstone Rock-bed can be seen in some ditches on the spurs above the village. The remarkable manner in which the stratum is here reduced to only a foot or two in thickness, while it has at the same time almost wholly lost its calcareous character and its hardness, is very striking; especially when we remember that the locality is only about four miles distant from that of Robin-a-Tiptoes, where the rock attains its maximum dimensions. But insignificant as the rock has become, it has still been able to resist denuding forces to a much greater extent than the clays above and below it, and consequently forms a well marked and very conspicuous escarpment.*

* Geol. Rutland, p. 72.

A trial-boring at Uppingham (1876) commenced near the top of the Upper Lias, was carried to a depth of 400 feet, mainly in clay, with only thin stone-beds here and there, but the record furnishes no clue whereby to distinguish the junction with the Middle Lias.

The Middle Lias has been well exposed in quarries to the west of Robin-a-Tiptoes, and again in the railway-cutting near Tilton station. In this district Prof. Judd noticed on top of the Marlstone, a bed two feet thick, of "Laminated, ferruginous, sandy and marly clay, forming a gradation from the Upper Lias Clay to the Middle Lias Rock-bed."* This is the "Transition Bed" previously described, and it has been carefully examined by Messrs. E. Wilson and W. D. Crick in the Tilton railway-cutting.† There it consists of flaggy limestone with its characteristic *Ammonites acutus*, but is scarcely separable from the Marlstone.

The section which I noted in the railway-cutting is as follows:—

| | | Ft. | In. |
|---|---|---|---|
| | Soil and Drift sand. | | |
| Upper Lias - | Blue clay and shales. | | |
| Transition Bed. | | | |
| Middle Lias. | Greenish and brownish marlstone, alternating in places with seams of crinoidal rock and presenting appearances of false-bedding - - - - about | 16 | 0 |
| | Micaceous sandstone and sandy shales, about | 20 | 0 |
| | Blue clays. | | |

Messrs. Wilson and Crick have published a list of fossils from the Marlstone of Tilton, including the Transition Bed, and this includes the following species of Ammonites:—*A acutus*, *A. annulatus*, *A communis*, *A. margaritatus*, *A. ovatus*, *A. serpentinus*, and *A. spinatus*. This shows the intimate connexion between Middle and Upper Lias, and corresponds with the evidence obtained at various points throughout the country from the Dorsetshire coast.

A large number of Gasteropods were obtained from the Transition Bed. The Middle Lias sandy shales have yielded *Am. margaritatus*, *Cardium truncatum*, &c. I obtained *Ammonites acutus* and *A. communis* from the upper part of the Marlstone, and these species are also recorded by Messrs. Wilson and Crick from beneath the Transition Bed. *Belemnites paxillosus*, *B. elongatus*, *Pecten æquivalvis*, *P. dentatus*, and *P. lunularis* occur also. *Rhynchonella tetrahedra* and *Terebratula punctata* are most abundant in the lower beds, where they occur in clusters.

The lower beds of the Marlstone are less massive than the upper, and at the base there are three, more or less nodular, bands, of greenish sandy rock weathering brown, the ferruginous staining resembling the "box-structure" of the Northampton Ironstone.

The beds are much more oxidized where they outcrop further north; and to the west of the railway there, are old ironstone-

* Geol. Rutland, p. 68.
† Geol. Mag. 1889, p. 296.

works. The digging of the ore has however been abandoned during the last three or four years (1889). Probably the crinoidal beds contribute to the poorness of the ore, although in places they have become decalcified. No doubt the best ore occurs where the beds come to the surface, and probably they could not be worked to advantage beneath any great thickness of clay.

Prof. Judd gives the total thickness of the Rock-bed as 18 ft. 6 in., a little in excess of my measurement at Tilton, but coinciding with that of Messrs. Wilson and Crick.

At the east end of the village of Billesdon, two brickyards, one on either side of the old coach-road from Uppingham to Leicester, furnished a valuable section of the strata about 10 feet below the Rock-bed; and this is described as follows by Prof. Judd:—

| | | |
|---|---|---|
| Middle Lias | Rock-bed. | |
| | Light-blue clays with bands of sandy ironstone (few fossils) - - | about 30 feet. |
| | Dark-blue clay with septaria (numerous fossils) - - - - | 15 feet seen. |

The upper part of the series appears to be very destitute of fossils, with the exception of a few fragments of *Belemnites*. Towards its base, however, the clay yields large flat septaria, some of which decompose by exposure to the air, and assume a reddish brown colour, rapidly falling to pieces. These septaria yield numerous organic remains. The blue clays at the base are sometimes very micaceous, and the septaria contain in their fissures Specular iron, Zinc-blende and Pyrites. The following fossils were obtained by Prof. Judd:—

| | |
|---|---|
| Ammonites margaritatus (abundant). | Pecten æquivalvis. |
| Belemnites paxillosus. | Modiola scalprum. |
| Plicatula spinosa. | Goniomya. |
| Lima pectinoides. | |

A brickyard at Rocart, south-west of Whissendine, noted by Prof. Judd, showed a good section of blue micaceous clays, yielding a fauna similar to that above mentioned. *Cardium truncatum* was especially abundant in the septaria.*

At a brickyard between Somerby and Ouston, Prof. Judd noted the following section:—†

| | | |
|---|---|---|
| Middle Lias | Soil. | |
| | Light-coloured clay only partially exposed. | |
| | Band of ironstone - - - | 6 inches. |
| | Blue, highly-micaceous, and pyritous clay - - - - - | 3 to 4 feet. |
| | Blue, sandy, calcareous and highly-micaceous rock, crowded, in places, with fossils - - - | 2 feet. |
| | Clay with bands of septaria - - | 21 feet to bottom of the pit. |

* Geol. Rutland, pp. 69, 70.
† Judd, *Ibid.*, p. 67.

Lower beds were exposed in brickyards at Great Gonerby, where beneath the floor of septaria, grey shales with bands of ferruginous septaria, and a layer with phosphatic nodules, rested on dark blue shaly clay with scattered nodules of cement-stone and septaria; these beds (beneath the floor of septaria) being upwards of 50 feet thick. The dark blue shaly clay has yielded the following fossils*:—

| | |
|---|---|
| Ammonites Engelhardti. | Palæoniso (Trochus) monoplicus. |
| —— margaritatus. | Pecten æquivalvis. |
| —— nitescens. | —— lunularis? |
| —— spinatus. | Goniomya hybrida. |
| Nautilus. | Gresslya Seebachi. |
| Belemnites. | Leda graphica. |
| Amberleya. | Pleuromya costata. |
| Trochus Acis? | Unicardium cardioides. |

The outcrop of the band with phosphatic nodules, has been represented on the Geological Survey map, at the places where it has been seen, from Gonerby northward to Lincoln, as it was the only horizon that could be traced. The clays below pass down into similar clays with *A. capricornus*, and in the absence of sections the boundary of Lower and Middle Lias is naturally doubtful.

Ironstone is again worked at Caythorpe, between Grantham and Lincoln, where the following section of the beds was noted by Mr. W. H. Dalton†:—

| | | Ft. | In. |
|---|---|---|---|
| | Soil and rubble | 4 | 0 |
| Middle Lias (Marlstone). | Inferior ironstone | 2 | 0 |
| | Good ironstone | 3 | 0 |
| | Limestone-band, slightly silicious | 0 | 9 |
| | Good ironstone | 10 | 0 |
| | Sandstone impregnated with iron-ore | 0 | 6 |
| | | 20 | 3 |

A boring made at this locality, after passing through the ironstone, was carried to a depth of nearly 300 feet for the most part in blue clay (Middle and Lower Lias).

Further north the Marlstone degenerates and in places we altogether lose the Rock-bed. In Mr. Ussher's opinion the absence of the Marlstone between Welbourn and Lincoln is due to a horizontal passage into or replacement by clay, the one kind of sediment dovetailing into the other. Hard, more or less concretionary and ferruginous beds represent the last appearance of the Marlstone in this area, and they are evidently much like the thin beds noticed near Market Harborough.

Near Wellingore there is a nodular bed with phosphatic concretions, and this together with layers of hard grey limestone with pyrites, and overlying shales (altogether 12 to 15 feet thick) represent the Marlstone, and have yielded the following fossils‡:—

* Jukes-Browne, Geol. S. W. Lincolnshire, p. 36.
† Geol. S.W. Lincolnshire, p. 40.
‡ *Ibid.*, pp. 37, 40-42.

| | |
|---|---|
| Ammonites communis | Pecten. |
| Belemnites. | Rhynchonella fodinalis. |
| Cardium truncatum. | —— tetrahedra. |
| Hinnites. | Waldheimia Waterhousei. |
| Lima punctata. | Terebratula punctata. |

Mr. W. H. Holloway remarked that this nodular band showed oolitic structure in places, and he compared it with the nodular bed seen elsewhere at the base of the Marlstone. This suggestion is important for we find a nodular bed extending onwards towards Lincoln at about the same horizon. It seems probable that the nodule-bed at Gonerby may be on the same general horizon. (See list of fossils from clay beneath, p. 240.)

Proceeding towards Lincoln we find the Middle Lias represented by clays, with occasional indurated bands of micaceous limestone and cement-stone nodules. In the railway-cutting west of Coleby the following fossils were obtained by Mr. Rhodes*:—

| | |
|---|---|
| Ammonites margaritatus | Cardium truncatum. |
| Belemnites. | Goniomya hybrida. |
| Amberleya (Eucyclus) imbricata. | —— v. scripta. |
| Turbo cyclostoma. | Pecten lunularis. |
| Cardita multicostata. | |

Gasteropods were numerous.

The old brickyard west of Waddington showed about 15 ft. of micaceous shaly clay with cement-stones, and here *A. margaritatus* and *Pecten æquivalvis* were obtained by Mr. Ussher and myself.

The brickyard south-east of Bracebridge showed the following section, in 1885:—

| | | Ft. | In. |
|---|---|---|---|
| Middle Lias | Bluish-grey and mottled clay with band of ferruginous cement-stones - - | 7 | 6 |
| | Nodule-bed, consisting of clay and ferruginous cement-stones, with phosphatic concretions - - - - - - | 1 | 0 |
| | Shale with two bands of ferruginous cement-stone - - - - - - | 3 | 0 |
| | Grey micaceous shaly clay with scattered cement-stones, and small nodules of pale earthy limestone near top: *A. margaritatus* about | 25 | 0 |
| Lower Lias | Dark blue marl with nodules: *A. capricornus*, *A. striatus*, &c. - - - about | 15 | 0 |

As before mentioned, *Ammonites capricornus* and less frequently *A. striatus*, occur in the clays and nodules for about 10 feet upward from the floor of the pit. During a previous visit, Mr. Rhodes obtained, from another part of the pit, and about 3 feet from the base, a specimen of *Ammonites margaritatus*: but as remarked by Mr. Ussher, the clays which yield *A. capricornus* abundantly, are probably below the site at which the former species was obtained. Owing to the easterly dip of the beds and the irregular working of the clays, the section varies from time to time.

* Geol. Lincoln, pp. 25, 26, &c.

Excepting in Yorkshire and (I may add) in Raasay, we have elsewhere no record of the occurrence of *A. capricornus* and *A. margaritatus* in the same stratum, but inasmuch as there is no recognizable plane of demarcation between the zones of these Ammonites, indicating any cessation in the continuity of deposit, it would not be very surprising to find the two species together, for the associated fossils indicate a blending of the zones. Indeed, in the list given by Mr. Ussher from the clays beneath the nodule bed, it has not been practicable to separate the species from the two zones.

From the nodule-bed the following species were obtained* :—

| | |
|---|---|
| × Ammonites margaritatus. | × Gresslya donaciformis. |
| Belemnites vulgaris. | × Pleuromya costata. |
| × Amberleya imbricata. | Plicatula spinosa. |
| Turbo. | × Unicardium cardioides. |
| Avicula cygnipes. | × Waldheimia perforata. |
| Ceromya petricosa (liassica). | |

The species thus marked × were obtained also from the clays below.

The higher beds of the Middle Lias, that have been exposed at Kirk and Parry's pit to the north-east of Bracebridge, consist of shales with ferruginous septaria; and about 6 feet above the "Nodule-bed" there was to be seen a band, described by Mr. Ussher as "Ferruginous rubble, suggesting a thin weathered representative of the Marlstone Rock-bed." This suggestion may account for the non-appearance of the rock-bed in places, as near Yeovil, where this thin layer is often so decomposed as to make no feature at the surface.

Among the fossils from this pit, above and below the Nodule-bed, may be noted *Ammonites nitescens, Leda graphica, L. imbricata, Avicula cygnipes, A. inæquivalvis, Arca Stricklandi, Cardium truncatum, Hippopodium, Inoceramus, Ostrea irregularis,* and *Pecten lunularis,* as well as some of the species noted from the nodule-bed at Bracebridge.

The Nodule-bed has been traced by the race-course, north-west of Lincoln, where it consists of ironstone with phosphatic pebbles. Of the lower beds, we rarely find exposures along the foot of the escarpment, north of Lincoln, but a few fossils have been obtained from a brickyard south-west of Hemswell.

Between Willoughton and Willoughton Grange, traces of an ironstone-bed were observed by Mr. Ussher, and these he takes to be indications of the *Pecten*-bed, which is an important horizon further north.

The Marlstone Rock-bed sets in north of Burton-by-Lincoln, and its narrow outcrop forms a foundation for a number of villages. There are however few exposures, and these furnish evidence of but 3 or 4 feet of hard ferruginous sandy limestone, sometimes crowded with fossils. *Ammonites communis, Belemnites breviformis, Cardinia crassiuscula, Pecten æquivalvis, P. lunularis, Waldheimia perforata, Terebratula punctata,* and other fossils have been obtained at South Carlton, Ingham, and Fillingham.

* Geol. Lincoln, p. 28.

In the northern part of Lincolnshire the succession of beds, grouped as Middle Lias by Mr. Ussher, is as follows:—*

Rock Bed.
Clay, with lines of nodules and septaria - - - .. 6 feet.
*Pecten*-bed ironstone.

The fauna of the *Pecten*-bed, and of part at any rate of the overlying clay, is rather that of the higher portions of the Lower Lias elsewhere, than that of the beds with *Ammonites margaritatus* exposed south of Lincoln. At present no specimens of *Ammonites margaritatus* have been found in the clay below the Rock Bed, while *A. capricornus* has been found in nodules that occur within a few feet of it. Hence on palæontological grounds there is a remarkable attenuation of the zone of *A. margaritatus*.

The Rock-bed is a grey and brown ferruginous limestone or ironstone, 7 to 10 feet thick. From the abundance of *Rhynchonella tetrahedra* it was named the *Rhynchonella*-bed by the Rev. J. E. Cross. It has been traced through Grayingham and Kirton Lindsey, and has been quarried in places between Kirton and Manton. The rock is here and there nodular, but nowhere rich enough in iron to be of value for smelting. Some fossils were obtained by Mr. Cross in the railway-cutting south of Santon Warren: these include *Ammonites spinatus*, *A. communis*, *Belemnites paxillosus*, *Terebratula punctata*, &c.†

Northwards the Rock-bed has not been well exposed, except at Winteringham, where it was observed by Mr. C. Fox-Strangways. Beyond this village it disappears beneath the Alluvium of the Humber.

### *Shropshire.*

The occurrence of Middle Lias, at Prees in Shropshire, was made known by Murchison in 1834. He remarked that the Marlstone was to be seen "in quarries and by the sides of the roads, dipping to the north-north-east at low angles;" and he recorded a number of fossils which clearly established the age of the strata.‡

During my examination of the district I was much indebted to Mr. Henry Ikin of Prees, who pointed out the spots where exposures of the beds were to be seen; and who had collected a series of fossils which he submitted to Messrs. Sharman and Newton for identification.

It will be seen that not only the Lower Lias, wherever evidence was to be obtained, but also the Middle Lias, presents the same general characters as are met with along the main outcrop of the strata in the midland counties.

The fossiliferous beds of sandy Marlstone have been opened up in graves in the churchyard at Prees, and from these beds Mr. Ikin has obtained many of the fossils mentioned. Here the thickness of the stone-beds is from 8 to 10 feet, including at the base,

* Geol. Lincoln, pp. 31, 32.
† Quart. Journ. Geol. Soc., vol. xxxi. p. 124.
‡ Proc. Geol. Soc. vol. ii., p. 115; and Silurian System, p. 23.

more sandy layers. Still lower beds are exposed in the road-cutting west of Prees church, and in old pits and slipped ground to the south. These comprise fissile, sandy, and micaceous beds, in places interbedded with micaceous loam, and passing down into more argillaceous strata (with nodules of earthy limestone) that throw out springs. These beds have been exposed to a depth of 20 feet. They contain *Belemnites* and *Ammonites margaritatus*, the latter poorly preserved.

At one spot on the hill south of Prees church, there was formerly a brickyard. The surface-beds were of a clayey nature, but there was no fossil evidence to prove their age, for being on slightly higher ground than the fossiliferous beds at Prees church, it is possible there may be traces of Upper Lias. The section showed 10 feet of fissile, slightly calcareous and micaceous loamy beds, with *Belemnites*, *Pentacrinus*, and small hard nodules; and the strata passed downwards into clay.

The following fossils from the Middle Lias of Prees, for the most part in the collection of Mr. Henry Ikin, were (with three exceptions) identified by Messrs. Sharman and Newton:—

Hybodus.
*Ammonites Engelhardti.
†‡—— margaritatus.
†—— spinatus.
Belemnites elongatus?
—— vulgaris?
Cerithium.
Chemnitzia.
Pitonnillus conicus.
Pleurotomaria helicinoides.
Turbo aciculus.
Dentalium.
Arca.
Astarte.
†Avicula novemcostæ.
Cardium truncatum?
†Gryphæa cymbium.
†—— gigantea.
Hinnites velatus.
Leda.
Lima pectinoides.
Macrodon intermedius.
*Modiola scalprum.
Ostrea.
†Pecten æquivalvis.
—— dentatus?
—— lunularis?
*Pholadomya ambigua.
‡—— Simpsoni.
Pleuromya costata.
Plicatula spinosa.
Unicardium cardioides?
†Rhynchonella acuta.
—— rimosa.
—— variabilis?
Terebratula punctata.
Waldheimia quadrifida.
—— resupinata?
‡Annelide tube.
Pentacrinus gracilis.
Eryon.

* Identified by the Rev. T. W. Norwood.
† Recorded also by Murchison.
‡ Obtained by H. B. Woodward.

# CHAPTER IX.

## UPPER LIAS.

### General Description.

This formation consists for the most part of bluish-grey clay and shale, with nodules of argillaceous limestone (cement-stones and septaria), and occasionally a good deal of selenite. The Basement Beds consist of pale earthy limestones and marls or clays, the bands of stone occurring sometimes in regular courses, but being often of an interrupted and nodular character; while the nodules enclose remains of Fishes and other organic remains.

These lower beds are usually opened up in quarries where the Marlstone is worked, and the junction is well-marked throughout the district, from the Dorset coast, where the Marlstone and Upper Lias stone are represented in a band about 2 feet thick, through the Midland counties to Lincolnshire. Stratigraphically this is one of the most definite boundaries in the series of Jurassic rocks, for lithologically, palæontologically, and in the sequence of strata there is rarely any difficulty in fixing the junction. The pale earthy limestones of these Basement-beds, resembling, as they often do in texture, beds of White Lias or of Great Oolite limestone, appear in marked contrast with the brown iron-shot or ferruginous Marlstone. In a few localities, however, where the Marlstone is thin, or has become much decomposed near the surface, the boundary across country cannot be traced without considerable difficulty.

Nevertheless there is no palæontological break between these formations. In Northamptonshire there is a thin layer known as the "Transition Bed," which by its fossils, links, the formations together; and generally throughout the country, we find common to both Marlstone and Upper Lias, such forms as *Ammonites annulatus*, *A. communis*, *A. crassus*, *A. Holandrei*, *A. serpentinus*, &c.* There is no authentic record, however, of the occurrence of *A. spinatus* above the horizon of the Marlstone or Transition Bed.

The thickness of the Upper Lias varies considerably in different parts of the country, and especially when we take into account the sandy and clayey beds that belong to the zone of *Ammonites jurensis*. Excluding, for the sake of convenience, the sandy beds, and taking only the mass of clays, together with the Basement Beds, we find the thickness of the Upper Lias in Dorsetshire to be about 70 feet, in Gloucestershire 100 to 200 feet, in Oxfordshire 30 to 100 feet, in Northamptonshire 150 to 160 feet, in Rutland-

* Day, Quart. Journ. Geol. Soc., vol. xix. p. 295; Judd, Geol. Rutland, p. 46 E. Wilson and W. D. Crick, Geol. Mag., 1889, p. 341.

shire 176 feet, in South Lincolnshire 200 feet, near Lincoln itself 100 feet, and further north in that county the thickness diminishes to 70, and probably to as little as 25 feet.

The clays that constitute the mass of the formation, shade up irregularly and gradually into the Sands at the base of the Inferior Oolite, from Dorsetshire to the Cotteswold Hills, so that here we have no definite stratigraphical division; but further north in Oxfordshire, Northamptonshire, and Lincolnshire, there is usually a marked divisional plane between the Upper Lias clay and overlying beds (Northampton Sands), accompanied here and there by the evidences of local erosion.

The Upper Lias has been subdivided into several zones, but somewhat differently by various geologists,* and this is not to be wondered at considering that the so-called zonal species, *Ammonites annulatus*, *A. serpentinus* (or *falcifer*), *A. communis*, and *A. bifrons*, occur together in the Basement Beds of the division. As a matter of general convenience, and having regard to the prevalence of certain species at particular horizons and to the associated fossils, the zones have been arranged in descending order as follows:—

| | | Zones. |
|---|---|---|
| Passage Beds | Sands and clays (Midford Sands in part, and Northampton Sands in part). | *Ammonites jurensis* (Fig. 77). |
| Clays (main mass of Upper Lias). | Clays and Shales | *Ammonites communis* (Fig. 73). |
| Basement Beds | Limestones, clays, and paper-shales (Fish and Insect Limestones, Leptæna Beds, and Transition Bed). | *Ammonites serpentinus* (Fig. 70) (or *A. falcifer*) and *A. annulatus*. |

The "Transition Bed," which is a fossiliferous layer a few inches thick, connecting the Middle and Upper Lias, has been for convenience described with the Middle Lias.

It may be mentioned that *Ammonites bifrons* can no longer be regarded as a zonal species, as it has far too wide a range, occurring throughout the Upper Lias. Dumortier indeed has treated the whole of the Upper Lias (below the zone of *A. opalinus*), as the zone of *A. bifrons*.

Objections might locally be urged against other zonal species, such as *A. striatulus*,† which occurs in the Basement Beds of the Upper Lias in Dorsetshire, while it has been recorded from the Fish and Insect Limestone of Byfield (on the authority of Dr. Wright). From the beds on the same horizon at Navenby in Lincolnshire, the species has been recorded (with a query) by Messrs. Sharman and Newton.‡

* Wright, Lias Ammonites, pp. 67, 116, 163; Judd, Geol. Rutland, p. 89; S. S. Buckman, Inf. Ool. Ammonites, p. 114, and Quart. Journ. Geol. Soc., vol. xlv. p. 440; B. Thompson, Rep. Brit. Assoc. for 1891, p. 384.

† This is probably the form recognized as *A. radians* by Day, Quart. Journ. Geol. Soc., vol. xix. p. 295. See also Judd, Geol. Rutland, pp. 82, &c.; F. Smithe and W. C. Lucy, Proc. Cotteswold Club, vol. x. p. 206.

‡ Ussher, Geol. Lincoln, p. 180.

Locally the zones have been further subdivided, and these minor zones or sub-zones will be mentioned in due course.

The fossils of the Upper Lias include species of *Ichthyosaurus*, *Pelagosaurus*, and *Steneosaurus*; but Saurian remains are by no means so abundant in the area under consideration as they are in Yorkshire. More important are the remains of the Fishes, especially *Leptolepis* and *Pachycormus*. Otolites have also been obtained.

Of Mollusca, *Ammonites* and *Belemnites* are plentiful throughout the formation, and species of *Nautilus* are not uncommon. The Gasteropods include *Amberleya* (*Eucyclus*), *Cerithium*, *Euomphalus* (?), *Pleurotomaria*, *Trochus*, *Turbo*, and *Turritella*. *Dentalium* is also found. Among the Lamellibranchs we find *Astarte*, *Cucullæa*, *Gresslya*, *Inoceramus*, *Leda*, *Lima*, *Monotis*, *Nucula*, *Ostrea*, *Pecten*, *Pleuromya*, *Posidonomya*, *Thracia*, and *Trigonia*.

Brachiopoda are far less abundant than in the Middle Lias: the species include *Discina*, *Leptæna*, *Lingula*, *Rhynchonella*, *Waldheimia* and *Thecidium*. Polyzoa are exceedingly rare.

The Crustacea include *Eryon*, *Palinurina*, *Penæus*, and some Ostracods. The Insects can only be mentioned, as the names require revision, but they include the Dragon-fly, *Libellula*. Of Annelides, *Ditrupa* and *Serpula* are fairly abundant. Echinoderms, with the exception of *Pentacrinus* are rare, but they include *Acrosalenia*, *Cidaris*, and *Hemipedina*. Corals also are rare, but *Thecocyathus* and *Trochocyathus* have been recorded. A number of Foraminifera have been obtained.† Lignite is found, but no plant-remains of recognizable species have been recorded.

In Yorkshire the lowest zone of the Upper Lias is known generally as that of *Ammonites annulatus*; but it was grouped with the Middle Lias by Messrs. Tate and Blake, on account of its yielding more Middle Lias than Upper Lias species; and among these they record *A. margaritatus*. As suggested by Mr. Walford (see p. 228) the Transition Bed of the country around Banbury, &c. may in point of age be equivalent to this zone, for it yields some of the same Gasteropods and other fossils.‡ Mr B. Thompson would also include in the same zone portions of the *Leptæna*-beds described by Charles Moore. In this southern part of England there was evidently a paucity of sediment as compared with the Yorkshire deposits, at the junction of Middle and Upper Lias.

At the bottom of the Upper Lias in the area from Somersetshire to Lincolnshire, there occur at intervals certain shales and limestones known as the Fish and Insect Beds. Attention was first called to these beds in Gloucestershire by the Rev. P. B. Brodie, and they were subsequently recognized in Somersetshire

* Yorkshire Lias, p. 171.

† See W. D. Crick and C. D. Sherborn, Journ. Northamptonsh. Nat. Hist Soc., vol. vii. p. 67.

‡ Fox-Strangways, Jurassic Rocks of Yorkshire, vol. i., p. 126.

by Charles Moore. In places the shales are finely laminated, and known as Paper-shales; but the beds from a fossiliferous point of view, as Fish and Insect Limestones, are not everywhere to be identified. As in the case of the Insect Limestones at the base of the Lower Lias, the distinctive fossils are preserved locally, and the fact that in places they cannot be recognized is no proof of the absence of equivalent strata. They are indeed intimately associated with the beds grouped as the zone of *Ammonites serpentinus*, not only in the area under consideration, but also in Yorkshire, for in that county we find remains of Fishes preserved in greatest abundance and variety at the same horizon. Hence for all practical purposes the thin representatives of the zone of *Ammonites annulatus*, together with the Fish and Insect Limestones and other beds belonging to the zone of *Ammonites serpentinus*, may be treated as one division forming the Basement Beds of the Upper Lias. (See also p. 246.) At the same time it must be borne in mind that the occurrence of limestone-bands is subject to variation, and that the Basement Beds shade upwards into the overlying clays grouped as the zone of *A. communis*.

Taking the Basement Beds as a whole, they are very fossiliferous, constituting Cephalopoda Beds as well as Fish and Insect Limestones. The following are the more abundant fossils* :—

---

* For fossils of the Transition Bed, see p. 229.

## UPPER LIAS CEPHALOPODA.

Fig. 70.

Fig. 71.

Fig. 73.

Fig. 72.

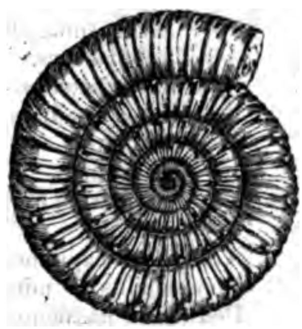


Fig. 74.

Fig. 75.

FIG. 70. *Ammonites serpentinus*, Rein. $\frac{1}{4}$.
" 71. " *cornucopia*, Y. and B.
" 72. " *fibulatus*, Sow. $\frac{1}{2}$.'

FIG. 73. *Ammonites communis*, Sow. $\frac{1}{3}$.
" 74. " *bifrons*, Brug. $\frac{1}{3}$.
" 75. " *elegans*, Y. and B. $\frac{1}{2}$.

Zones of *Ammonites annulatus*, and *A. serpentinus* (including the Fish and Insect Limestones and Leptæna Beds).

Lepidotus gigas.
Leptolepis concentricus.
—— constrictus.
Pachycormus curtus.
—— macropterus.
Tetragonolepis discus.
Ammonites annulatus.
—— bifrons (Fig. 74).
—— cæcilia.
—— communis (Fig. 73).
—— cornucopia (Fig. 71).
—— crassus (raquinianus).
—— elegans (Fig. 75).
—— exaratus.
—— falcifer.
—— heterophyllus (Fig. 76).
—— Holandrei.
—— Levisoni.
—— lythensis.
—— serpentinus (Fig. 70).
—— subplanatus.
Nautilus astacoides.
Belemnites quadricanaliculatus.
—— subtenuis.
—— tripartitus
—— tubularis (Fig. 78).
—— vulgaris.
Amberleya capitanea (Fig. 81).
Euomphalus (?) minutus (Natica pilula).
Dentalium liassicum.
Inoceramus dubius (Fig. 80).
Lima eucharis.
Nucula Hammeri.
Pecten pumilus.
Posidonomya Bronni (Fig. 82).
Koninckella (Leptæna) Bouchardi.
—— liasiana.
Leptæna Moorei.
Rhynchonella jurensis.
—— Moorei.
Waldheimia Lycetti.
Serpula.
Pentacrinus jurensis.

*Ammonites annulatus*, *A. communis*, *A. crassus*, *A. fibulatus*, and *A. Holandrei* are species very closely connected. *A. elegans*, Sow. (often mistaken for *A. concavus*) is regarded as the same as *A. complanatus*, D'Orb., and *A. subplanatus*, Oppel, by Tate and Blake.* (See p. 229.)

* Yorkshire Lias, p. 306; see also G. Barrow, Geology of North Cleveland, p. 35.

## Upper Lias Fossils.

Fig. 76.

Fig. 77.

Fig. 78.

Fig. 79.

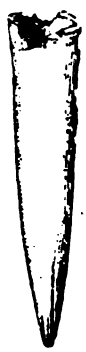


Fig. 80.

Fig. 81.

Fig. 82.

Fig. 83.

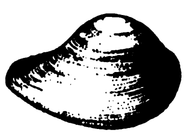


Fig. 76. *Ammonites heterophyllus*, Sow. $\frac{1}{4}$
„ 77. „ *jurensis*, Ziet., Midford Sands. $\frac{1}{4}$
„ 78. *Belemnites tubularis*, Y. and B. $\frac{1}{3}$
„ 79. „ *Voltzi*, Phil. $\frac{1}{2}$.
„ 80. *Inoceramus dubius*, Sow. (nat. size).
„ 81. *Amberleya capitanea*, Goldf.. Upper Lias and Inferior Oolite. $\frac{3}{4}$
„ 82. *Posidonomya Bronni*, Voltz (nat. size).
„ 83. *Leda ovum*, Sow. (nat. size).

It should also be mentioned that the form usually identified as *Ammonites serpentinus* is considered by Mr. S. S. Buckman to be *A. falcifer*; he would, therefore speak of the zone as that of *Ammonites falcifer*. In the majority of cases, however, these so-called species have not been distinguished; by many authorities they are regarded as synonymous, and in the following pages the name *A. serpentinus* will be used in a comprehensive sense, to include the varietal forms or "mutations" sometimes separately indicated as *A. falcifer*, and *A. Strangwaysi*.

The zone of *Ammonites communis* is usually taken to include the mass of clays between the Basement Beds and the sands and clays of the zone of *A. jurensis*; in this sense it is here adopted, although Prof. Judd and others have employed it as a general term for both Basement Beds and overlying clays.* Other divisions have been suggested, and to these references are made in the sequel. Locally the zone may, to some extent, be represented in the Basement Beds, as in Dorset and parts of Somerset.

On the whole these clays yield many fossils, but locally some beds are comparatively unfossiliferous, the shells probably having been destroyed; for sclenite, in these instances usually abundant, may be regarded as the product of their decomposition and of that of iron-pyrites.

Zone of *Ammonites communis*.

Ammonites bifrons (Fig. 74).
—— communis (Fig. 73).
—— cornucopia (Fig. 71).
—— crassus.
—— elegans (Fig. 75).
—— exaratus.
—— fibulatus (Fig. 72).
—— heterophyllus (Fig. 76).
—— Holandrei.
—— Levisoni.
—— lythensis.
—— semicelatus.
—— serpentinus (Fig. 70).
—— subcarinatus.
Belemnites apicicurvatus.
—— elongatus.
—— ilminsterensis.
—— subtenuis.
—— Voltzi (Fig. 79).
—— vulgaris.
Nautilus astacoides.
Cerithium armatum.
Trochus duplicatus.
Turritella Dunkeri.
Dentalium liassicum.
Astarte striato-sulcata.
Avicula substriata.
Cucullæa elegans.

* Geol. Rutland, p. 89.

Gresslya donaciformis.
Inoceramus cinctus.
—— dubius (Fig. 80).
Leda ovum (Fig. 83).
Nucula claviformis.
—— Hammeri.
Pecten pumilus.
Pleuromya costata.
Thracia glabra.
Trigonia pulchella.
Discina reflexa.
Serpula tricristata.
Pentacrinus jurensis

The zone of *Ammonites jurensis*, together with the overlying zone of *A. opalinus*, are in parts of the west of England associated for stratigraphical purposes, under the name of the Midford Sands. Such a division may be looked upon as forming a connecting link between the Lias and the Oolites, constituting as it does passage-beds from the one group to the other. Under such circumstances it matters little whether we treat the Midford Sands under the heading of Lias or Oolites, and as a matter of convenience we shall note the details with the newer formation, for they cannot well be treated separately, on account of their intimate stratigraphical association.

On general grounds it is thought desirable to draw the line between Lias and Oolites in the midst of this series of passage-beds, and most authorities agree in placing the zone of *A. jurensis* with the Upper Lias, and that of *A. opalinus* with the Inferior Oolite. This divisional plane, such as it is, is here adopted on palæontological grounds, although it must be admitted that on stratigraphical grounds the general division of Midford Sands is the most important one to represent on the Geological Survey Maps in the country from Dorsetshire to Gloucestershire. That zones transgress the limits of stratigraphical divisions is admitted; and the researches of Mr. S. S. Buckman (to which more attention will be drawn in our next volume) show that in Dorsetshire the zone of *A. jurensis* extends below the stratigraphical limits of the Midford (or Bridport) Sands. Moreover in the Midland counties the Northampton Sands, which include the zone of *Ammonites opalinus*, include also a portion, at any rate, of the zone of *A. jurensis*.

Notwithstanding the separation of these strata into the zones of *A. jurensis* and *A. opalinus*, there is no unanimity amongst geologists on the precise palæontological division between these zones, for other minor zones have been introduced, and the more attentively the beds are studied the less reason do we find for fixing any special plane of division, where the sequence is complete.

## UPPER LIAS.

### Local Details.

#### *Dorsetshire.*

In the cliff-section at Thorncombe Beacon, and on top of the adjoining Down cliff, we can trace about 70 feet of blue micaceous marly and sandy shale. The beds are inaccessible, but they are seen to merge upwards into the Midford Sands, which are shown to a thickness of about 100 feet at the Beacon. At the base of this mass of blue shale, is the thin layer of pale argillaceous limestone (Basement Bed of Upper Lias) welded to the top of the Middle Lias, and before described as the Junction-bed. These beds are also seen at Allington near Bridport. (See Fig. 41, p. 52.)

Owing to the thinness of the rock-beds at the junction of Middle and Upper Lias there are no quarries along this horizon by Netherbury and Burstock, between Bridport and Ilminster, and the Basement-beds of the Upper Lias are not to be seen.

Moreover the shales of the Upper Lias are often very sandy in character, and much like the beds immediately under the Marlstone Rock-bed; we find no uniform mass of dark clays and shales, such as occur in Gloucestershire, and further north; so that having only occasional sections in the deep lanes, it is very difficult to mark the boundaries of the formations, and over the greater part of the country between Bridport and Bath the Upper Lias was omitted from the Geological Survey Map.

We have in fact a mass of clay or shale, which merges upwards into the Midford Sands, and is not in this area separated by any prominent rock-bands from the soft sandy and shaly beds of the Middle Lias. The presence of the formation is indicated by the clayey nature of the ground, and could no doubt be traced continuously with the aid of the 6-inch maps, but in isolated sections it is not possible, in the absence of stratigraphical and palæontological evidence, to determine the age of the beds. Thus the age of the laminated clays and sands at Chalkway between Winsham and Cricket St. Thomas was not to be determined. (See p. 202.)

Mr. S. S. Buckman has recently obtained from the upper part of the blue shale at the Down cliffs (about 12 feet or more from the top) several Ammonites, one species of which he was enabled to determine as *A. radians*, a form found also in the yellow sands above.* This fact agrees with the stratigraphical evidence, of the intimate connexion between the clays and sands, and suggests that possibly the whole of the Upper Lias shale of Dorsetshire may belong to the zone of *A. jurensis*. No fossils are recorded from the lower portions (the main mass) of the shales. It must be borne in mind that the range of individual species of Ammonites may be

* Quart. Journ. Geol. Soc., vol. xlvi. p. 519; and H. B. W., *Ibid.*, p. 521.

locally restricted, but it is not so generally defined in the Upper Lias, that the occurrence of two or three specimens would enable us to fix a chronological horizon; nor are authorities sufficiently agreed on the definition of species to justify very dogmatic statements. Forms identified as *A. radians*, and which may be taken at any rate as closely allied, have been recorded from the lower beds of the Upper Lias of the Midland counties,* and *A. aalensis* is noted from the same beds in Yorkshire.† (See p. 199.) Mr. J. F. Walker, however, records *A. toarcensis* from one of the Basement Beds at Shipton Long Lane, Bothenhampton, and *A. striatulus* (which I have also obtained) from the uppermost Basement-limestone at North Allington.‡ (See p. 200.) He takes these species as affording evidence of the zone of *A. jurensis* in portions of the Basement Beds. *Rhynchonella Bouchardi*, which occurs in a lower layer at Shipton Long Lane, is characteristic of the lowest portion of the Upper Lias.

The general tendency of the evidence obtained here and at Ilminster, points to the conclusion that the zone of *A. communis* is less conspicuously developed than it is in the Midland counties and further north, and that it may locally be confined to the Basement-portion of the Upper Lias.

### *Somersetshire.*

The Upper Lias in the neighbourhood of Ilminster and Yeovil has been studied in much detail by Charles Moore. The lower beds are usually exposed in the quarries where the Marlstone is worked, but the higher and more clayey portion of the group is seldom exposed, though it may be traced beneath the sands at the base of the Inferior Oolite.

Locally Moore found it convenient to make the following divisions:—§

| | |
|---|---|
| Upper Lias | Ammonite Beds or Upper Cephalopoda Beds. |
| | Saurian and Fish Bed. |
| | Leptæna Clays. |

These beds were exposed in a quarry at Strawberry Bank, on the north of Ilminster.

The *Leptæna Clays* lie in immediate contact with the Marlstone, and consist of about 18 inches of green, yellow, and brown laminated clays, yielding *Leptæna* (*Koninckella*) *Bouchardi* and *L. Moorei* at the base, and higher up *Thecidium rusticum*, *Alaria unispinosa*, *Spiriferina ilminsterensis*, and *Zellania liassica*. Foraminifera and Ostracoda likewise occur, as well as *Terebratula globulina*, *Rhynchonella pygmæa*, *Ammonites*, and occasional remains of Fishes and Saurians.

The *Saurian and Fish Bed* consists of nodular yellow earthy limestone, usually blue hearted, and occurring in flat irregular elongated and lenticular masses, rarely more than five inches

* Judd, Geol. Rutland, p. 79; Walford, Proc. Warwickshire Field Club, for 1878.
† Tate and Blake, Yorkshire Lias, p. 303.
‡ Rep. Brit. Assoc. for 1890, p. 799.
§ Proc. Somerset Arch. and Nat. Hist. Soc., vol. xiii. pp. 120, 132.

thick and sometimes septarian. These enclose various organisms, Saurians, Fishes, Cephalopoda, Insects, and Crustacea. Coprolites are also found in the nodules. As remarked by Moore, the shape of the nodules conforms roughly to that of the enclosed organism, so that his experienced eye enabled him to predict with confidence the fossil that would be presented to view when particular nodules were split open. It, must, however be stated that a large proportion of the nodules yield no organisms, and this fact has created much disappointment to those who have gone in search of the bed, and apparently failed in their efforts to find it.

The Saurians are represented by *Ichthyosaurus acutirostris* and *Pelagosaurus typus* (*temporalis*). Of the *Pelagosaurus*, very fine examples were obtained by Moore, one belonging to a diminutive reptile only 13 inches long, and this has been named *P. Moorei* by E. Deslongchamps (M.S., 1876). These and other specimens are placed in the Bath Museum.

The Fishes include *Pachycormus macropterus*, *P. curtus*, *Lepidotus*, *Leptolepis concentricus*, *L. constrictus*, and species of *Hybodus*, &c.*

The Cephalopoda (in addition to *Ammonites*) include *Geoteuthis* and *Teudopsis*, and as Moore remarks "the softer parts of these cuttle fishes have perished, leaving only the internal cuttle bone, in the centre of which the ink-bag is usually found, still charged with its black pigment." Among other Mollusca, Moore records *Inoceramus dubius*, *Posidonomya Bronni*, &c.

The Crustacea (determined by Dr. H. Woodward) include *Eryon Moorei*, *Palinurina pygmæa*, *Penæus latipes*, *Eryma elegans*, *Hefriga*, and *Glyphea*.

The Insects and some Plant-remains have yet to be determined. Moore obtained a specimen of fossil wood, bored by Lithodomi, and with a number of Cirripedes attached to it.

These Leptæna Clays and Saurian and Fish Bed, clearly belong to the Basement Beds of the Upper Lias, representing (in part) the same beds at Churchdown and Dumbleton in Gloucestershire. Mr. B. Thompson regards the Leptæna Beds (in part) as equivalent to the Pleurotomaria Bed on the Dorset coast, and the Transition Bed of Northamptonshire.†

The "*Upper Cephalopoda Beds*" were taken by Moore to include all the other beds of the Upper Lias to the sands at the base of the Inferior Oolite; but his description indicates other portions of the Basement Beds (zone of *A. serpentinus*) above the Saurian and Fish Beds, as well as the zone of *A. communis*. These comprise clays with bands of rubbly and earthy limestone having a thickness of 8 feet. The clays above, which are of variable thickness, and of considerable importance near Yeovil, were not clearly recognized by Moore; but he records in his list of fossils

* Mr. A. Smith Woodward has in preparation a Monograph on these Upper Lias Fishes.

† Rep. Brit. Assoc. for 1891, p 849.

from the "Upper Cephalopoda Beds" certain species (*e.g.*, *Ammonites radians*, *A. variabilis*, &c.), whose occurrence is suggestive of the passage-beds that link the Lias with the Inferior Oolite.

The "*Upper Cephalopoda Beds*" also yield *Belemnites*, many Gasteropods (*Cerithium*, *Onustus*, *Pleurotomaria*, &c.) *Inoceramus dubius*, *Leda ovum*, &c., together with Brachiopods, Echinoderms, Corals, Foraminifera, &c.

*Ammonites annulatus*, *A. bifrons*, *A. communis*, *A. crassus*, and *A. serpentinus* occur generally in the Basement Beds of the Upper Lias of Somerset.

The Upper Lias has been exposed in quarries at Down Lane (Earn Hill), east of Donyatt; at Moolham and Tortwood Hill; and by the lane leading to Ashwell, on the north of Ilminster. These sections usually show the flat nodules of yellowish earthy limestone belonging to the Saurian and Fish Bed, but as remarked by Moore they are occasionally absent. As a rule the quarries show, on top of the Marlstone, 5 or 6 feet of blue and brown marly clay with thin irregular interrupted and nodular bands of pale earthy limestone, in which the common Ammonites of the Basement Beds are usually abundant.

The sections at Tortwood Hill show the following succession of beds:—

| | | Ft. | In. |
|---|---|---|---|
| Upper Lias (Basement Beds). | Rubbly limestone and clay - - - ; Pale grey compact limestones and marly clay; *Ammonites annulatus*, *A. bifrons*, *A. communis*, *A. Levisoni*, *A. serpentinus*, *Belemnites* - - - - - | 3 | 9 |
| | Lenticular masses of pale earthy limestone with yellowish coating (Fish Bed); *A. serpentinus* - - - - - - | 0 | 3 |
| | Clay with "race" and occasional band of earthy limestone - 0 ft. 9 in. to | 1 | 4 |
| Middle Lias (Marlstone). | Pale earthy and sandy limestone, much iron-stained; with large *Belemnites* (abundant) - - - - - ; Sandy marl - - - - - | 0 | 6 |
| | Brown sandy and grey iron-shot limestones, much jointed and iron-stained; *Belemnites* (abundant), *Pecten æquivalvis*, *Gryphæa gigantea*, *Terebratula*, *Rhynchonella* - | 7 | 0 |
| | Ferruginous sandy clay - - - | 0 | 6 |
| | Limestones as above, seen to depth of - | 3 | 0 |

The thin layer of limestone and marl on top of the main mass of Marlstone may represent the Transition Bed of Northamptonshire.

The Saurian and Fish Bed and the *Leptæna*-beds are noted by Moore in a section at Kingston, south-west of Ilminster, "but the former is only represented by a few very flattened nodules, in which no organisms have been found, some of the nodules not being larger than a crown-piece." He adds that about half a mile north of the Kingston section, in the range in which the Strawberry Bank quarry is situated, there was a quarry in a

large field south of the White Lackington road, where all the zones were observed.*

Near the Sevingtons, at Boxtone Hill, Hurcot, to the east of Atherstone, and at Stocklinch Ottersey, quarries have been opened in Middle and Upper Lias. At Shepton Beauchamp the *Leptæna*-beds, Saurian and Fish Beds, and Upper Cephalopoda beds have been noticed by Moore, and he has observed them also to the north-east of Yeovil, in a quarry overlooking the village of Rimpton.

A section south of Shepton Beauchamp church, showed nearly 7 feet of the Upper Lias Basement Beds, but it did not differ materially from sections at Tortwood Hill. Moore records two species of *Trochocyathus* from the Upper Lias at this locality.

The Upper Lias is also shown at Stoke pit, east of Holy Tree, between West Stoke and South Petherton; and at Norton, near Ham Hill (see p. 204).

West of Yeovil, by Alvington, and Brympton, micaceous sandy shales are seen, and here the Upper Lias forms a broad tract at the foot of the escarpment formed by the Sands at the base of the Inferior Oolite; while the Basement Beds extend towards the Middle Lias escarpment in a thin covering, that coincides roughly with the dip-slope (2° to 4°), over the country through Preston to Brimsmoor Tree. (See Fig. 66, p. 206.)

The Stone-beds have been opened up east of Montacute station, where the following section was to be seen:—

| | | Ft. | In. |
|---|---|---|---|
| Upper Lias | Micaceous sandy clay | 5 | 0 |
| | Pale limestones | 6 | 0 |
| Middle Lias | Rock Bed. | | |

Here, and also between Lufton and Lower Odcombe, the limestones at the base of the Upper Lias are 3 feet 6 inches thick, and these beds are separated by little or no clay. Near Yeovil they become of sufficient importance to have been quarried for building-purposes.

These beds are seen above the Marlstone in quarries west and south-east of Brimsmoor Tree, and north-west of Preston. They are about 3 feet 6 in. thick, consisting of light earthy and rubbly limestones, overlaid by about 4 feet of brown ferruginous loamy clay. From these quarries the following fossils were obtained by Mr. J. Rhodes and myself, and named by Messrs. Sharman and Newton:—

Ammonites communis.
—— crassus.
—— heterophyllus.
—— serpentinus.
Belemnites.
Lima.
Rhynchonella.
Serpula.
Pentacrinus.

* Proc. Somerset Arch. and Nat. Hist. Soc., vol. xiii. p. 135; see also S. S. Buckman, Quart. Journ. Geol. Soc., vol. xlv. p. 450.

The Upper Lias stone here is sometimes used for the foundations of new roads, paths, &c., but the quarries are opened mainly for the Marlstone.

Near Yeovil, at the Green Quarry, on the Mudford Road, to the south of Picketty, pale-earthy and iron-stained white limestone, known as the Yeovil Stone, was formerly quarried for building-purposes. The beds are from 3 ft. 6 in. to 6 ft. thick. The Stone (together with that from Ham Hill) was used in building Yeovil church, and in the construction of the Cemetery buildings.

South of Picketty, the stone was exposed beneath 12 feet of laminated micaceous shale with calcareous bands, the beds becoming bluer and more shaly towards the base. These beds above the Yeovil Stone, are very similar to the micaceous sandy shales, which in a lane-cutting by Picketty, are shown beneath the Marlstone; that rock being there brought near the surface by a fault. Formerly there was a brickyard at Picketty where 5 feet of clay was worked above the Yeovil Stone, the beds having a westerly dip.

At the Union Pit, the beds seen were as follows:—

| | | | Ft. | In. |
|---|---|---|---|---|
| Upper Lias | Loam | | 5 | 0 |
| | Micaceous sandy shale | | 4 | 0 |
| | White limestone | | 3 | 6 |
| Middle Lias | Marlstone | 1 ft. 0 in. to | 1 | 6 |

The sandy micaceous shales above the Yeovil Stone, contain thin indurated layers of calcareous sandstone and rotten ferruginous sandstone, locally known as "Ingotton." Owing to their partially pervious nature, they have given much trouble at the cemetery, where their thickness is about 50 or 60 feet. The entire thickness of these shaly beds must be about 120 feet.

At Harwood's brick-kiln, about 15 feet of brown laminated micaceous sandy loam was exposed; and about a mile further north, another brickyard, in Brickyard Lane, showed 6 feet of bluish-grey slightly micaceous clay, with occasional nodules of blue limestone, resting on micaceous marly clay, containing a "lism" or layer of sandy ferruginous limestone with *Pecten julianus*. A well penetrated the beds to a further depth of 38 feet, without touching any stone. No other organic remains were to be found; and I failed to find any outcrop of the Marlstone (Rock-bed) to the north-east. The clays at Brickyard Lane are "heavier" than those at Harwood's kiln, while to the south-east the beds (on a lower horizon) are still heavier; the dip is here westerly, corresponding with that E. of Picketty. The beds unfortunately like those (which they much resemble) in the brickyards at Mudford, afford no distinctive fossil remains; laminated sandy shales here as elsewhere being bad preservers of organic remains. The beds at Mudford belong to the Middle Lias; those now described, are no doubt Upper Lias, judging by the evidence of a well-boring at the Yeovil gas-works, where the Marlstone was reached at a depth of 132 feet.

The Upper Lias is persistent wherever the strata can be observed in the area between Ilminster and Yeovil, and again between Yeovil and Castle Cary, although it has been shown on the Geological Survey Map only over a small area near Sandford Orcas and Corton Denham, where it was surveyed by Bristow.

The fact that the Upper Lias comprises sandy shales much like those beds below the Marlstone, has led to some inconsistency in the mapping of this region. At the same time, judging from the observations of Moore and Bristow, the Upper Lias appears to be very thin in some places in the areas above mentioned.

Whether these sandy shales represent the zone of *Ammonites communis*, or, as is more likely, partly that zone and portions of the zone of *A. jurensis* can only be determined on fossil evidence, and that at present is not forthcoming.

A pit north-west of Trent Barrow, north-east of Trent, showed the following section:—

| | | Ft. | In. |
|---|---|---|---|
| Upper Lias (Basement Beds). | Ferruginous loam and clay - - - | 3 | 0 |
| | Pale grey and bluish mottled earthy limestone - - - - - - | 0 | 6 |
| | Grey marly clay, with *Ammonites communis*, *A. bifrons*, *Belemnites* - - - | 0 | 8 |
| | Earthy iron-stained limestones, with *A. communis*, *Belemnites*, *Pentacrinus* - - Nodular ochreous marl and limestone - | 3 | 3 |
| | Pale earthy limestone and marl - - Grey marly clay with nodules of limestone | 0 | 11 |
| Middle Lias - | Tough brown and grey sparry limestone, with pale grey marly stone, on top, in places, and compact pale limestone-kernels. Oolitic in places. *Belemnites* - | 1 | 3 |
| | Clayey beds. | | |

The Marlstone is here quarried for road-metal. The Upper Lias "rubbish" is not now used, although Moore noted two layers of building-stone. *Ammonites serpentinus* and *A. annulatus*, occurred in the debris.

In sections near Rimpton and Sandford Orcas, Moore noted the presence, above the Marlstone, of the *Leptæna* Beds, Saurian and Fish Bed, and "Upper Cephalopoda Beds," as previously noted in sections near Ilminster; but as he observes, the equivalents of these "zones" cannot always be recognized in the area.

In his section at the "Home Ground Quarry," Compton (now closed, but probably situated between Over Compton and Nether Compton), Moore stated that the highest band of Upper Lias stone was much eroded, while resting on it was dark clay with oolitic grains (2 inches), and mottled brown clay (2 feet). These overlying beds he grouped with the "Inferior Oolite." Sections elsewhere show "piping" of the rock-beds; and this was probably the case with the bed in question, and the overlying clays should rather be grouped with the Upper Lias.

The Basement Beds of the Upper Lias were exposed above the Marlstone near Sutton Montis, but afforded no special features.

From South Cadbury northwards by Castle Cary and Batcombe, to the neighbourhood of Doulting and the Mendip Hills, we have no sections showing the Upper Lias; but as this formation is well shown in the outliers of Pennard, Glastonbury Tor, and Brent Knoll, there can be little doubt that the beds are present in the escarpment. It will be found that the same obscurity prevails along the escarpment of the Cotteswold Hills, while the outliers afford good sections of the strata.

Glastonbury Tor rises to a height of a little over 500 feet above sea-level. This remarkable conical hill, a monument, as it were, of the denudation of surrounding areas, is capped by the Midford Sands, which form a knoll, based on a platform of Upper Lias clay and stone. Beneath come the thin Marlstone Rock-bed, the micaceous sands, and the shales, previously described. (See p. 208, and Fig. 84, p. 263.) The upper beds may stated as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Midford Sands. | Sands with occasional beds of calcareous sandstone - - - about | 174 | 0 |
| Upper Lias Clay and Basement Beds. | Brown and bluish clay with *Belemnites* - | 35 | 0 |
| | Pale earthy and compact limestones (iron-stained) and clays, with *Ammonites bifrons*, *A. communis*, *A. crassus*, *A. serpentinus*, *Belemnites*, *Nucula*, and *Rhynchonella Moorei* - - - - - | 14 | 0 |
| Middle Lias - | Marlstone, &c. | | |

Unfortunately the quarries where the Upper Lias was exposed, have been abandoned, and the beds are no longer to be seen. The beds were referred to by Smeaton as the "Yellow Snake-stone" of Glastonbury.

To the east of West Pennard there were several small quarries showing the Basement Beds of the Upper Lias and the Marlstone. The following section is taken from one of them:—

| | | Ft. | In. |
|---|---|---|---|
| | Rubble and brown clay - - - | 1 | 0 |
| Upper Lias - | Clayey bed full of fossils, *Ammonites communis*, *A. crassus*, &c. - - - | 1 | 6 |
| | White and pale bluish-grey earthy limestone and marly clays with "race" - - | 3 | 0 |
| Middle Lias - | Marlstone; Tough bluish rock with irony grains - - - - - - | 1 | 3 |
| | Micaceous sands with *Belemnites*. | | |

Here the roads have been mended with Upper and Middle Lias stone, and with specimens of *Ammonites serpentinus*, *A. bifrons*, and *A. communis*.

Brent Knoll presents the same structure as Glastonbury Tor, with the addition of a thin rock-bed on top of the Sands, from which I obtained fossils that link it with the Cephalopoda Bed at the base of the Inferior Oolite of the Cotteswold Hills. (See

Fig. 85.) The Knoll, as at Glastonbury, is formed of the Sands, which rest on a platform of Upper Lias. Here pale earthy and rubbly limestones, with *A. communis*, *A. bifrons*, &c., are turned up in the ploughed fields, and may be traced on the brow of the platform, west of the hill. In a lane-cutting west of East Brent church, pale grey and mottled bluish-grey limestone yielding *A. communis* was exposed. The general section is as follows *:—

| | | | Ft. | In. |
|---|---|---|---|---|
| Midford Sands | Thin rock-bed (Cephalopoda-bed), and Sands | about | 200 | 0 |
| Upper Lias | Clay with bands of limestone at base | „ | 40 | 0 |
| Middle Lias | Rock-bed and micaceous sands | „ | 80 | 0 |
| | Micaceous shales and clays | „ | 130 | 0 |

In the neighbourhood of Kilmersdon and Radstock, we have no certain evidence of Upper Lias, although there is a considerable thickness of blue micaceous clay between the stone-beds of the Lower Lias and the Inferior Oolite. Where positive evidence is obtained, however, the Upper Lias is very thin, and the mass of the clays belongs to the Middle Lias: beds that have been termed "Marlstone," proving by their fossils to occupy a much lower horizon, as remarked by Moore, than the Rock-bed at Ilminster and other places. Hence there may be local breaks between the Upper and Middle Lias in the area between Bath and the Mendip Hills. (See p. 211.)

Several species of *Leptæna* and *Thecidium* are recorded by Moore from beds of Lias that occur in veins and fissures of the Carboniferous Limestone at Whatley.

The Basement Beds of the Upper Lias, with *Ammonites bifrons*, *A. communis*, *Belemnites tripartitus*, &c., have been noticed at Dundry Hill by Mr. Etheridge.† The entire thickness of the Upper Lias and of the overlying Midford Sands, appears to be reduced to about 10 feet.

Near Bath the Upper Lias is but poorly represented in its calcareous and argillaceous type. The Basement Beds, from 4 to 6 ft. thick, have been noticed by the Rev. H. H. Winwood at Dundas, and again in the railway-cutting near Devonshire Buildings, Bath.‡ They yield *Ammonites bifrons*, *A. communis*, *A. crassus*, *A. serpentinus*, *Lingula*, *Waldheimia Lycetti*, *Rhynchonella Moorei*, &c. Similar beds, about 12 feet thick, were noted by Moore, at Oaks Lane, Upton Cheney.

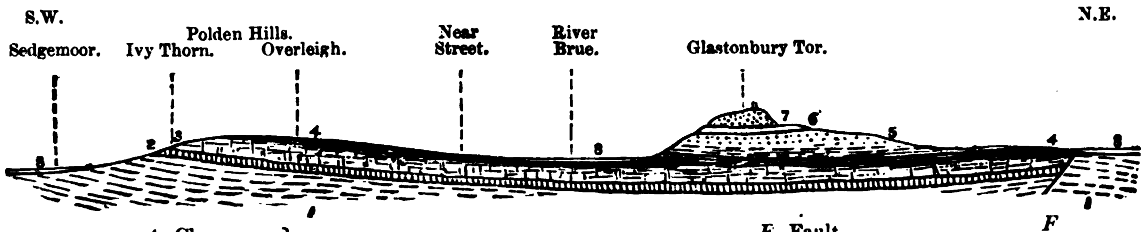
These beds of Upper Lias have not been shown on the Geological Survey Map, owing to their meagre development; but it is probable that the Upper Lias increases in thickness northwards, from Batheaston towards Marshfield.

* H.B.W., Proc. Bath Nat. Hist. Club, vol. vi. p. 125.

† Quart. Journ. Geol. Soc., vol. xvi. p. 21; and W. W. Stoddart, Proc. Bristol Nat. Soc., vol. ii. p. 30.

‡ Proc. Bristol Nat. Soc., vol. iii. p. 68; and Proc. Geol. Assoc., vol. iii. p. 92. See also Moore, Proc. Somerset Arch. Soc. vol. xiii. p. 153; H. B. Woodward, Geol. East Somerset, p. 115; and Phillips, Geol. Oxford, p. 117.

FIG. 84. *Section across the Polden Hills and Glastonbury Tor, Somersetshire.*




4. Clays } Lower Lias.
3. Limestones } Lower Lias.
2. Rhætic Beds.
1. New Red Marls (Keuper).

*F*. Fault.
8. Alluvium.
7. Midford Sands.
6. Upper Lias.
5. Middle Lias.

FIG. 85. *Section of Brent Knoll, Somersetshire.*

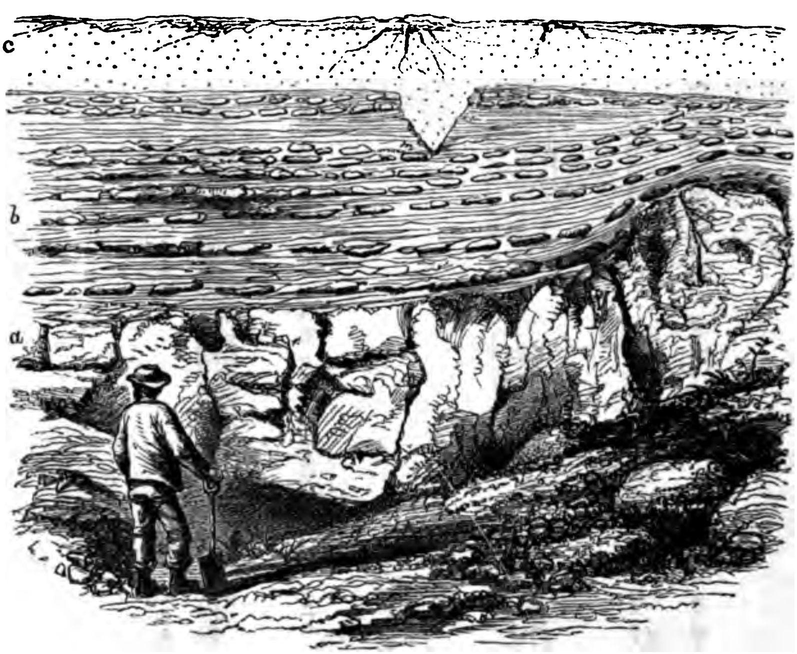

*a*. Cephalopoda-bed (top of Midford Sands).
*b*. Midford Sands.
*c*. Upper Lias.
*d*. Middle Lias (Marlstone and Sands).
*e*. Middle Lias (Clays).

*Gloucestershire.*

In the Cotteswold District the Upper Lias is not often exhibited,* nor has it been mapped in the escarpment south of Wotton-under-Edge, although probably present in an attenuated form. It is, however, mapped in the Oolitic escarpment stretching north from Wotton, by Dursley and Uley. (See Fig. 67, p. 214.)

The general characters of the lower beds of Upper Lias and the Marlstone are shown in the accompanying section at Wotton-under-Edge. (Fig. 86.)

FIG. 86. *Section at Wotton-under-Edge.* (H. W. Bristow.)




*a.* Marlstone. *b.* Upper Lias. *c.* Surface soil.

At a quarry to the south of Stancombe, and about 1 mile west of Dursley, Bristow noted the following section in 1843:—†

| | | |
|---|---|---|
| Midford Sand | - | Sand, about 3 feet. |
| Upper Lias | - | Clay, with bands of nodular blue claystone, 8 or 9 feet. |
| Middle Lias | - | Marlstone Rock, in thick beds, irregular. |

At Newnham (Newent) quarry, north of Stinchcombe Hill, the Upper Lias basement-beds have likewise been exposed; but sections of the higher beds, belonging to the zone of *A. communis* are rarely to be seen.

* See Brodie and Buckman, Quart. Journ. Geol. Soc., vol. i. p. 221.
† See also Wright, Quart. Journ. Geol. Soc., vol. xii. p. 307.

At Frocester Hill beneath the Midford Sands, Prof. Buckman noted 20 feet of Upper Lias shales, very micaceous, resting on a band of white limestone 1 ft. thick (with *Ammonites bifrons*, &c.), with shales below.* *A. serpentinus* has also been recorded from this neighbourhood, together with traces of the Saurian and Fish Bed, by Moore. Lycett records *Posidonomya Bronni* from the Upper Lias shale near Nailsworth.†

East of the railway-station at Brimscombe, there is a brickyard which showed the higher beds of the Upper Lias clay and the passage-beds into the overlying Midford Sands. The section showed brown loams and sands, resting on blue micaceous clay with a few cement-stones, and iron-pyrites. The total thickness of the Upper Lias near Stroud is estimated by Witchell at about 70 feet. There is also a brickyard at Rock Mill, South of Pitchcomb, near Painswick.

The higher beds of the Upper Lias contain nodules of cement-stone, and these according to Prof. Hull occur "in profusion in some of the brooks on the sides of the Cotteswold Hills, especially that on the southern base of Crickley Hill." He mentions sections of the beds in brickyards at Colesborne, and near Andoversford.‡

At Sandwell Park, west of Andoversford a cutting on the Great Western Railway showed the following section :—

| | | |
|---|---|---|
| Midford Sands | Rubble of oolite with *Rhynchonella cynocephala*, &c. | |
| | Micaceous blue and brown sandy loam | 40 or 50 feet. |
| Upper Lias Clay. Zone of *Ammonites communis*. | Blue micaceous clay with cement-nodules, septaria and pyrites, with *Nucula*-bed near top : *Ammonites bifrons*, *A. annulatus*, *A. communis*, *A. Holandrei*, *A. lythensis*, *Belemnites elongatus*, and *Arca*. | |

The fossils were named by Messrs. Sharman and Newton.

The Upper Lias Clay forms somewhat irregular and lumpy ground on the slopes, near Andoversford and Charlton Kings. Its thickness at Leckhampton has been estimated at 200 feet.§

The section at Churchdown (called Chosen) Hill has been worked out in much detail during the past 30 years, by the Rev. F. Smithe.‖ He has given the following section :—

| | | Ft. | In. |
|---|---|---|---|
| | Soil with Drift pebbles | 1 | 6 |
| Upper Lias (Basement Beds). | Brown marly clay | 2 | 0 |
| | Concretionary argillaceous limestone (Fish-bed) | 0 | 6 |
| | Mottled blue and drab clays with Crustacea | 6 | 0 |
| | Brown marly shale (Leptæna Band) | 1 | 0 |
| | Blue and yellow clay | 1 | 0 |
| Middle Lias | Yellow marly sands, with ferruginous concretions, and nodules with Ostracoda | 6 | 0 |
| | Marlstone rock, impure ferruginous limestone, blue-hearted | 10 | 0 |

* Quart. Journ. Geol. Soc., vol. xiv. p. 103; see also Wright, *Ibid.*, vol. xii. p. 303

† The Cotteswold Hills, pp. 23, 24.

‡ Geol. Cheltenham, p. 24.

§ Hull, Geol. Cheltenham, Plate 2.

‖ Proc. Cotteswold Club, vol. iii. p. 40, and vol. vi. p. 374.

From the Upper Lias Dr. Smithe has recorded *Leptolepis concentricus*, *Pachycormus*, *Ammonites communis*, *A. bifrons*, *A. annulatus*, *A. lythensis*, numerous Gasteropods, some Lamellibranchs and Brachiopods (the last-named including the tiny *Leptæna Moorei*), Crustacea, &c. The section compares well with those near Ilminster; while the yellow marly sands, which have yielded *Bourguetia turbinata*, &c. may include the Transition Bed of the Midland Counties.

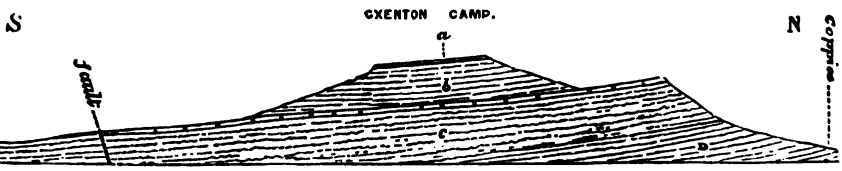
At Stanley Hill, west of Winchcomb, the following section was noted by Moore and the Rev. P. B. Brodie in 1856* :—

| | | Ft. | In. |
|---|---|---|---|
| Clay and vegetable soil | | 4 | 0 |
| Upper Lias (Basement Beds). | Saurian and Fish Bed | 1 | 0 |
| | Blue clay | 5 | 0 |
| | Grey laminated clay [including Leptæna Beds] | 14 | 0 |
| Middle Lias - | Marlstone | 3 | 6 |

The sections in this neighbourhood are sometimes referred to under the locality of Gretton, a village on the north side of the hill.† Upper Lias also occurs on Oxenton Hill. (See Fig. 87, and Fig. 68, p. 218.)

Fig. 87.

*Section across Oxenton Hill, near Winchcomb, Gloucestershire.*
(Prof. E. Hull.)




*a.* Inferior Oolite. *c.* Middle Lias (with Marlstone on top).
*b.* Upper Lias. *d.* Lower Lias (clays).

The Upper Lias of Dumbleton has long been a noted locality for its "Fish-bed" and for remains of Insects. A large collection of the fossils was formed by Miss Holland, of Dumbleton,‡ and the beds have been described by many geologists.§

The total thickness of the Upper Lias of this neighbourhood is estimated at 150 feet by the Rev. P. B. Brodie, but it is the lower beds, exposed on the hill that rises between the villages of Alderton and Dumbleton, to which attention has been prominently

* Proc. Somerset Arch. and Nat. Hist. Soc., vol. xiii. p. 148.

† See F. Smithe and W. C. Lucy, Proc. Cotteswold Club, vol. x. p. 209.

‡ Wright, Proc. Cotteswold Club, vol. iii. p. 153.

§ Brodie, Geologist, vol. i. p. 230; Fossil Insects, p. 55; Quart. Journ. Geol. Soc., vol. v. p. 32, and Proc. Cotteswold Club, vol. ii. p. 133; Murchison, Geol. Cheltenham, ed. 2, by Buckman and Strickland, pp. 35, 36; Buckman, Proc. Geol. Soc., vol. iv. p. 211; F. Smithe and W. C. Lucy, Proc. Cotteswold Club, vol. vii. p. 149; R. F. Tomes, Geol. Mag., 1886, p. 108; B. Thompson, Journ. Northampton Nat. Hist. Soc., vol. iii. p. 188.

directed. The quarries are no longer worked to the extent that was formerly the case, but the one sometimes noted as Alderton quarry, was at the south-eastern corner of the hill, while the Dumbleton quarry was towards the east.

The Fish-bed is an interrupted band of limestone formed of yellow nodules, blue inside, evidently much like the Fish-bed of the Upper Lias of Ilminster. It has yielded remains of Saurians, and of the Fishes *Leptolepis*, *Pachycormus*, and *Tetragonolepis discus*; Insects including forms allied to *Libellula*; and Cephalopods with the Ink-bag preserved.

About 2 feet above the Marlstone, Mr. R. F. Tomes obtained two species of Corals, *Thecocyathus tuberculatus* and *Trochocyathus*. *Ammonites Holandrei*, *A. serpentinus*, *Aptychus*, *Belemnites*, *Euomphalus* (?) *minutus*, and *Inoceramus dubius*, have also been recorded. So that altogether there is a remarkable similarity between the beds and those of the neighbourhood of Ilminster, although in Gloucestershire these Basement Beds are much thicker than are the equivalent strata in Somersetshire.

Prof. Judd in 1875, suggested that the name "Dumbleton Series" might be applied to these Paper-shales with Fish and Insect Limestones*; and it is a name that may be useful when we wish to particularize these fossiliferous beds. Nevertheless, as elsewhere remarked, the preservation of the characteristic fossils is somewhat local and independent of the sedimentary accumulations, and although we have evidence of these Fish and Insect Limestones at intervals from Somersetshire to Lincolnshire, it is hardly possible to make any general stratigraphical distinction between them and the beds grouped as the zone of *Ammonites serpentinus*.

The section at Alderton (Dumbleton), in 1887, was as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Upper Lias (Basement Beds). | Brown clay with blocks of pale-grey earthy limestone. Belemnites | 1 | 6 |
| | Pale marly clay | 6 | 6 |
| | Paper-shales with lenticular earthy and fissile shaly limestone (Fish and Insect Bed) in the upper part; the beds are brown on top and bluish-grey below, passing down into paper-shales with crushed Ammonites<br>Shales with *Leptæna* | about 20 | 0 |
| Middle Lias | Hard brown sandy ferruginous and micaceous limestone, with *Ammonites spinatus*, *Belemnites* (abundant), *Nautilus*, *Avicula inæquivalvis*, *Limea acuticosta*, *Pecten æquivalvis*, *P. lunularis*, *Pleuromya costata*, *Rhynchonella tetrahedra*, &c. (seen to depth of 3 feet). | | |
| | Micaceous and sandy shales with ironstone-nodules, *Belemnites*, *Pleuromya costata*. | | |

The quarry has for some time been abandoned, and the lowest beds of the Upper Lias were not clearly shown. A list of the

* Geol. Rutland, pp. 58, 79.

fossils has been lately published by Dr. F. Smithe, and Mr. W. C. Lucy.*

The Upper Lias outcrops on the northern side of Bredon Hill, where its thickness was estimated by Mr. Howell at about 100 feet. It has been traced continuously around the northern end of the Cotteswold Hills, and in some of the deep inlying valleys, although as remarked by Prof. Hull, its outcrop is for the most part concealed by oolitic detritus.† In the outlier of Ebrington Hill, its thickness has been estimated at 120 feet, by Mr. S. G. Hamilton.

There are few sections on the eastern side of the Cotteswolds, bordering the Vale of Moreton, but the beds were exposed in a brickyard near Broadwell. Upper Lias clay was exposed at the base of the Inferior Oolite Series, in the railway-cutting west of Bourton-on-the-Water; no sections are known near Clapton or the Rissingtons; but the clay has been dug for brick- and tile-making to the north of Sherborne. Its thickness in this neighbourhood has been estimated at from 40 to 70 feet. Further east, along the borders of the Evenlode Valley, the thickness diminishes.

### *Oxfordshire.*

The Upper Lias is exposed here and there in the valley of the Windrush to a point a little east of Burford. In the Evenlode Valley it has been exposed at Fawler, where beneath the Inferior Oolite the following beds were shown:—

| | | Ft. | In. |
|---|---|---|---|
| Upper Lias | Blue clay with occasional small cement-stones and ironstone-concretions - 12 ft. 0 in. to | 13 | 0 |
| | Brown earthy limestone, with ironstone above and below - - - - - | 3 | 0 |
| | Pale earthy and ferruginous limestone, with *Ammonites annulatus*, *A. bifrons*, *A. communis*, *A. crassus*, *A. serpentinus*, *Belemnites ventralis* - - 0 ft. 2 in. to | 0 | 3 |
| Middle Lias - | Marlstone (Iron-stone). | | |

The Upper Lias at the tunnel north of Chipping Norton was estimated by Mr. Beesley to be from 30 to 36 feet thick. He did not observe any of the limestone-bands at the base of the formation, as met with at Bloxham and elsewhere; but the beds apparently were not clearly exposed down to the base.‡

A thickness of nearly 50 feet was proved in a well at Kingham Hill, further north; a well near Bloxham proved 60 feet, while near Banbury the thickness is about the same.

In the railway-cuttings west of Hook Norton, the Upper Lias clays (zone of *Am. communis*) were well shown beneath the Inferior Oolite series, and there many fossils have been collected

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* Proc. Cotteswold Club, vol. x. p. 202.
† Geol. Cheltenham, pp. 24, 25.
‡ Proc. Geol. Assoc., vol. v. p. 180.

by Mr. Beesley,* Mr. E. A. Walford,† Mr. J. Windoes, and myself. They include the following species:—

| | |
|---|---|
| Ammonites annulatus. | Belemnites subaduncatus. |
| —— bifrons. | —— vulgaris. |
| —— communis. | Arca elegans. |
| —— crassus. | Inoceramus dubius. |
| —— fibulatus. | Leda ovum. |
| —— elegans (subplanatus?). | Nucula. |
| Belemnites acutus. | Discina reflexa. |
| —— ilminsterensis. | |

The clays contain small nodules of limestone. Here and elsewhere in the neighbourhood of Banbury, *Ammonites fibulatus* appears to be the prevalent Ammonite in the clays. Only a few of the specimens found, are in a perfect condition, most of them having lost their inner whorls. It is a species intimately linked with *A. Holandrei*. (See p. 250.)

The Upper Lias has been traced in straggling outliers and inliers, from Chipping Norton to Tysoe Hill, near Compton Wynyate, and Shenlow Hill, west of Shenington. The main outcrop passes through Great Tew, and borders the Cherwell valley at Steeple Aston and Upper and Lower Heyford.

Whether or not the Upper Lias, or indeed any portion of the Lias extends beneath Oxford is not known. The evidence of the saline waters met with in an artesian well at St. Clement's Brewery, Oxford, led Prof. Prestwich to suggest that the Oolites there rested directly on the New Red Sandstone Series.‡ In the Burford Signett boring the thickness of the Upper Lias has been estimated at 82 feet, and at Wytham near Oxford at about 14 feet. At Wytham moreover there appears to be a thickness of 170 feet of Lower and Middle Lias; and if this be true, the Lias probably does extend below Oxford.

The junction of Upper Lias (Basement Beds) and Marlstone has been well exposed in the railway-cutting east of Bloxham station. The section is as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Upper Lias | Grey and brown ferruginous clay with selenite; with, at, or near the base, a Pentacrinite bed, a thin layer made up almost entirely of Crinoidal remains, with much pyrites. | | |
| | Red ferruginous loamy layer with ironstone-nodules - - - - - - | 0 | 5 |
| | Blue and grey marly clay with thin bands of grey ferruginous nodular earthy limestone. *Ammonites communis, A. bifrons, A. serpentinus*, &c. - - - - - - | | |
| | Pale grey earthy limestones - - - | | |
| Middle Lias | Earthy iron-shot limestone, and compact banded ironstone (in places). | | |
| | Brown and bluish-green marlstone, with Crinoidal bed in places near the top, about | 20 | 0 |
| | Blue and brown micaceous sandy shales (base not seen) - - - - - | 3 | 0 |

* Proc. Geol. Assoc., p. 169. See also Hudleston, *Ibid.*, p. 388.
† Quart. Journ. Geol. Soc., vol. xxxix. p. 229.
‡ Paper read before the Ashmolean Society, Oxford, June 12, 1876.

The Basement Beds of the Upper Lias are here very rich in Ammonites, yielding in addition to those mentioned. *A. annulatus, A. crassus, A. cornucopia,* and *A. heterophyllus;* also *Belemnites acutus, Amberleya, Avicula, Ostrea, Plicatula,* &c.*

The beds further eastward in the railway-cutting, are slightly faulted in two or three places—the Upper Lias being brought abruptly in contact with an upthrust mass of Marlstone.

At the brickyards about a mile from Banbury, on the road to Broughton, the Upper Lias clay is dug for making red bricks and drain-pipes. On the south side of the road there were exposed about 10 feet of bluish-grey and brown shaly clays, with thin ironstone bands and selenite. North of the road, about 30 feet of bluish shaly clays, mottled blue and brown on top, were exposed. The clay is more or less micaceous, it contains much selenite, small limestone-concretions and many ochreous and pyritic nodules. There are occasional irregular bands of grey earthy limestone, exhibiting 'cone-in-cone' structure. *Ammonites fibulatus* is the characteristic fossil, a few bivalves also occur, but fossils on the whole are scarce. Mr. Walford estimates the full thickness of the Upper Lias at this locality at 50 feet.

Upper Lias fossils may occasionally be found on top of the Marlstone or in crevices of the rock on Edge Hill, and the Rev. P. B. Brodie informs me that he there found fragments of the Fish Bed; but no definite traces of the strata are preserved. Further north there is an outlier of the Upper Lias, capped by Northampton Sands, on the Burton Hills, near Burton Dassett.

* See T. Beesley, Proc. Geol. Assoc., vol. v. p. 168; and Wright, Lias Ammonites (Palæontograph Soc.), p. 128.

# CHAPTER X.

## UPPER LIAS—(*continued*).

### *Northamptonshire.*

THE Upper Lias of Northamptonshire and districts to the north-east, has been divided as follows, mainly in accordance with the divisions adopted by Prof. Judd* :—

| | |
|---|---|
| Zone of *Ammonites communis.* | Leda-ovum Beds.<br>Clays with few fossils (Unfossiliferous Beds of B. Thompson).<br>Communis Beds. |
| Zones of *A. serpentinus* and *A. annulatus,* (Basement Beds). | Serpentinus Beds.<br>Paper Shales with Fish and Insect Limestones.<br>Transition Bed. |

The Paper Shales consist of finely-laminated bluish-grey shales, poorly developed in Northamptonshire (1 ft. to 18 ins.), but containing a band, or nodular masses, of pale grey or brown argillaceous limestone, a few inches thick, which yields Fish-remains and occasional remains of Insects. This division may be correlated with the lowest beds of the Upper Lias at Dumbleton in Gloucestershire.

Saurian bones are rarely found. The Fishes include *Lepidotus elvensis, Leptolepis concentricus,* and *Pachycormus.* Otolites of Fishes have also been found. The Ammonites include *A. bifrons, A. communis, A. cornucopia, A. crassus, A. elegans,*† *A. Holandrei, A. Levisoni, A. serpentinus,* and *Aptychi.* Among other fossils are *Belemnites* (rare), *Inoceramus dubius, Euomphalus* (?) *minutus,* &c. Lignite and Jet are occasionally met with, and the occurrence of Coprolites was noted by the Rev. P. B. Brodie. Mr. Beeby Thompson notes that the Fish-bed consists of fissile nodules which are not concretionary, but appear in most instances to have been rounded by percolating water. (See p. 319.)

The "Serpentinus" Beds consist of marly clays with an overlying thin band, or nodules, of soft sandy and sometimes ferruginous limestone ("Lower Cephalopoda Bed"); and they are about 5 feet thick. Mr. Thompson records Saurian bones (rare), *Ammonites bifrons* (rare), *A. communis, A. exaratus, A. Holandrei, A. serpentinus* (*falcifer*), *Belemnites, Nucula Hammeri,* Gasteropods, &c.

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* Geol. Rutland, pp. 79, 89; see also B. Thompson, Journ. Northamptonshire Nat. Hist. Soc., vol. iii. p. 186.

† Including the forms known as *A. complanatus* and *A. subplanatus*; for such forms the name *A. radians* was employed by Prof. Judd.

The "Communis" Beds consist of grey and blue marly and shaly clay, 2 to 8 feet thick, surmounted by flaggy and nodular limestone bands ("Upper Cephalopoda Bed") about 1 ft. 6 inches in thickness. The stone is sometimes oolitic, according to Mr. Thompson. He records *Ammonites bifrons*, *A. communis* (very abundant), *A. cornucopia*, *A. Holandrei* (abundant), *A. semicelatus*, *A. serpentinus* (*falcifer*), *Belemnites canaliculatus*, *B. irregularis*, *Trochus duplicatus*, *Nucula Hammeri*, *N. claviformis*, &c.

It will be noticed that the name "Communis Beds" is applied, locally, to the lower part of the zone of *A. communis*; neither palæontologically nor stratigraphically is this division distinctly separable from the Basement Beds of other localities, but as it is considered to be somewhat local, it may be taken as an indication of the fact elsewhere noted, that the Basement Beds shade up into the overlying strata. (See p. 248.)

The upper part and indeed the main mass of the Upper Lias in this, as in most other tracts, consists of blue clay with nodules of limestone and septaria.

In his detailed notes on the Upper Lias of Northamptonshire Mr. Beeby Thompson has subdivided the clays as follows:—

| | |
|---|---|
| Upper Lias Clay | Upper Leda-ovum Beds = "Jurensis" Zone (in part). |
| | Middle Leda-ovum Beds. |
| | Lower Leda-ovum Beds or Cerithium Beds. |
| | Unfossiliferous Beds. |

Among the more abundant fossils that have a wide range, are *Ammonites bifrons*, *A. cornucopia*, *A. heterophyllus*, *A. serpentinus* (*falcifer*), *Arca elegans*, *Euomphalus* (?) *minutus*, *Inoceramus dubius*, and *Leda ovum*. *Belemnites* occur more or less abundantly.

The total thickness of the Upper Lias in the boring on the Kettering road near Northampton, was 153 feet; and at Duston, 190 feet.*

The "Unfossiliferous beds" consist of dark blue pyritic clay, 60 feet and upwards in thickness. Selenite is abundant, and jet is also found.

Calcareous spar exhibiting cone-in-cone structure and known as "Nail-head Spar" is also found in the upper part of the beds.† Occasionally fossils are obtained, and Mr. Thompson records *Ammonites bifrons*, *A. communis*, *A. Holandrei*, *A. serpentinus*, *Cerithium*, *Inoceramus dubius*, and *Nucula Hammeri*.

The occurrence of such unfossiliferous beds, accompanied by selenite, may be attributed simply to the destruction of the organic remains and the consequent formation of selenite. Nevertheless locally the beds seem to occur along a fairly persistent horizon.

The Lower Leda-ovum beds are distinguished by the abundance of small Gasteropods, especially *Cerithium armatum*, and by the prevalence of *Ammonites fibulatus* and *Nucula Hammeri*. Among other species recorded by Mr. Thompson, are *Ammonites bifrons*, *A. crassus*, *A. Holandrei*, *Nautilus*, *Actæonina*, *Euomphalus*(?) *minutus*, *Arca elegans*, *Dentalium liassicum*, *Inoceramus dubius*, *Leda ovum*, *Pecten pumilus*, *Discina reflexa*, &c.

No distinguishing fossils are noted from the Middle Leda-ovum Beds, which in fact form but a passage from the lower to the higher stages of this clay-division, and do not constitute a group of any special value.

* H. J. Eunson, Quart. Journ. Geol. Soc., vol. xl. p. 486; B. Thompson, Middle Lias of Northamptonshire, p. 101.

† This structure occurs also in the Upper Lias of Yorkshire. See p. 277, and Strangways, Jurassic Rocks of Yorkshire, pp. 127, 386.

In the Upper Leda-ovum clays, the fossils occur mostly in clusters in hard nodules, and among them Mr. Thompson records the following:—

| | |
|---|---|
| Saurians. | Astarte minima. |
| Ammonites bifrons. | × Cardium (Protocardium) substriatulum. |
| —— cornucopia. | × Gresslya abducta. |
| —— elegans. | Inoceramus dubius. |
| —— heterophyllus. | Modiola gregaria (cuneata ?). |
| —— Lilli (near to A. comensis ×). | × Avicula substriata. |
| × —— lympharum. | Ostrea sandalina. |
| Belemnites (several species). | Pecten demissus. |
| Dentalium (gracile) elongatum. | Trigonia northamptonensis (near to T. literata ×). |
| —— liassicum. | × Discina reflexa. |
| Euomphalus (?) minutus. | Lingula Beani (not found in lower beds). |
| Arca elegans. | |

The species marked × are recorded by Messrs. Tate and Blake from the zone of *Ammonites jurensis*,* and Mr. Thompson is of opinion that this zone may to a certain extent be represented in Northamptonshire, by these Upper Leda-ovum clays.

The total thickness of the Leda-beds in Mr. Thompson's opinion cannot be less than 50 feet; but estimates are necessarily rather doubtful, as the subdivisions of the Leda-ovum Beds "merge gradually one into the other."

A number of Foraminifera from the Leda-ovum Beds, have been described by Messrs. W. D. Crick and C. D. Sherborn.†

As Mr. Thompson remarks, in Northamptonshire there is no difficulty in deciding the stratigraphical boundary between the Upper Lias and Inferior Oolite, for the junction between the two formations is, as a rule, sharply defined, and sometimes presents evidence of an unconformity. The Basement-beds of the Inferior Oolite (Northampton Sands) here belong mainly to the zone of *Ammonites opalinus*, but they contain, not uncommonly, specimens of *A. jurensis*, wherefore the zone of *A. jurensis* is to some extent represented in the Northampton Sands.‡

The fact that the junction is often very sharply defined, and that there is evidence of local erosion would suggest that portions of the zone of *A. jurensis* were in places unrepresented, and this appears to be the case. On the other hand "at one or two places, there is evidence of a passage from the Upper Lias to the Inferior Oolite, with, apparently, only a slight cessation of deposit." I have seen instances of this gradation.

Comparing the Basement-beds of the Inferior Oolite (Northampton Sands) with the Dogger of Yorkshire, there is evidence of much agreement in general structure and fossil contents; but there is no evidence at present of the occurrence in Northamptonshire at this horizon, of *Ammonites striatulus* and other Ammonites that characterize the underlying shales in Yorkshire. The absence of these Ammonites cannot alone be taken as proof of any break in the sequence, but the stratigraphical and palæontological

* Yorkshire Lias, p. 190; see also Fox-Strangways, Jurassic Rocks of Yorkshire, vol. i. p. 136.

† Journ. Northamptonsh. Nat. Hist. Soc., vol. vii. p. 67.

‡ Thompson, Journ. Northampton Nat. Hist. Soc., vol. v. p. 75; E. T. Newton, Geol. Mag., 1891, p. 493. See also S. S. Buckman, Journ. Northampton Nat. Hist. Soc., vol. vi. p. 7.; Mr. Buckman regards the form found in the zone of *A. opalinus* as deserving a distinct name, and he has called it *Ammonites* (*Lytoceras*) *Wrighti.*

facts are interesting as affording some evidence of a local break in the zone of *A. jurensis*. As Mr. Thompson points out, sandy conditions came on earlier in the west of England than in the midland counties, and the general assemblage of fossils met with on the same horizon would be liable to the variation due to different conditions of the sea-bed.* (See also p. 246.)

To the north-east of Banbury the lower beds of the Upper Lias have been exposed in numerous sections, which have been described by Prof. Green,† Mr. Beesley,‡ Mr. E. A. Walford,§ and Mr. Beeby Thompson.|| The sections are of interest as furnishing evidence of the "Transition Bed" before mentioned, that occurs between the Middle and Upper Lias. Sections have been opened up near Chacombe, Middleton Cheney, Thenford, Hellidon, and other places. There the Basement-Beds of the Upper Lias consist of clays and white earthy limestones, varying a good deal in detail, from 6 to 9 feet thick, and yielding the usual Ammonites. At Thenford some Fish-remains were obtained by Mr. Beesley, but the various fossil-horizons have only locally been identified. (See Fig. 88.)

FIG. 88.

*Section in a Quarry South of Thenford, Northamptonshire.*
(Prof. A. H. Green.)


A. Surface-soil and Rubble.
B. Marlstone Rock-bed.
C. Upper Lias clays, with two beds of earthy limestone.
x Fault.

In the higher part of the Ouse Valley the outcrop of the Upper Lias occupies an extensive tract, being a portion of the main mass which skirts the Cherwell valley to the south-west. Details of one or two sections will be sufficient to indicate the characters of the beds seen in this district.

* Journ. Northamptonshire Nat. Hist. Soc., vol. vi. p. 99.
† Geol. Banbury, p. 8.
‡ Proc. Warwickshire Field Club, 1872, p. 23.
§ See references on. p. 228.
|| Journ. Northampton Nat. Hist. Soc., vols. iii. to vi.

The following section on the East and West Junction Railway south of Byfield, was recorded by Mr. Beeby Thompson:—*

| | | | | Ft. | In. |
|---|---|---|---|---|---|
| | | | Soil and Clay - - - - - | 3 | 0 |
| Upper Lias. | Zone of *Ammonites communis*. | | Upper Cephalopoda Bed. Flaggy limestone with *Ammonites communis, A. bifrons, A. Holandrei, Belemnites, Pecten, Astarte*, &c. | 0 | 6 |
| | | | Clay-marl with concretions; *A. communis, A. bifrons*, "Falcifer" Ammonites, *Belemnites, Astarte, Pentacrinus*, &c. - - - | 3 | 0 |
| | Zone of *A. serpentinus*. | "Serpentinus" Beds. | Lower Cephalopoda Bed. Hard sandy limestone with *A. serpentinus, A. exaratus, A. Holandrei, A. communis, Belemnites*, &c. - | 0 | 9 |
| | | | Light coloured marl, *A. communis* (rare), *Belemnites* - - - - - - | 2 | 6 |
| | | Fish and Insect Beds. | Shale, with flattened *Ammonites, Belemnites*, Fish Scales - - - - - | 0 | 1 |
| | | | Fish Bed, nodular limestone, *Ammonites communis, A. crassus, A. serpentinus, Euomphalus* (?) *minutus*, &c. - - - | 0 | 4 |
| Transition Bed - | | | Dark blue and red sandy clay - - | 0 | 3 |
| | | | Yellowish sandy and marly layer. *A. acutus*, Gasteropods, &c. - - - - - | 0 | 4 |
| Middle Lias. | Marlstone - | | Rock Bed, brown ferruginous marlstone with *Waldheimia resupinata*, &c. - - | 10 | 0 |
| | | | Blue Clay. | | |

The following section near Milton Malsor or Middleton, near Northampton, has also been recorded by Mr. Thompson† :—

| | | | Ft. | In. |
|---|---|---|---|---|
| Upper Lias. | Zone of *A. serpentinus*: with Fish and Insect Beds. | Soil - - - - - - - | 1 | 0 |
| | | Light coloured marl with *Ammonites communis*, &c. - - - - - | 1 | 10 |
| | | Cephalopoda Bed. Pale irregular limestone with "Falcifer" Ammonites, *Belemnites*, &c. - - - - - - | 0 | 6 |
| | | Clay and paper-shale with Fish-remains - | 0 | 6 |
| | | Fish Bed. Nodules of fissile sandy limestone, with Fish-remains, *Ammonites, Euomphalus* (?) *minutus*, Lignite, &c. - | 0 | 3 |
| | | Paper-shale with Fish-remains - - | 0 | 2 |
| Transition Bed - | | Red sandy clay - - - - ; Fossiliferous sandy marl - - - | 1 | 0 |
| Middle Lias - | | Rock Bed - - - - - - | 4 | 0 |

In this area the Fish Bed was noticed many years ago by the Rev. P. B. Brodie, who gives details of the section at Bugbrook.‡ From that locality a fine specimen of *Lepidotus elvensis* was obtained by Miss Baker, and eventually placed in the British Museum.

The Upper Lias clay has been exposed in the railway-cutting west of Brackley railway-station, and in an adjoining brickyard. It consists of blue and grey clay with race, selenite, and small cement-stones.§ Another brickyard north-east of the town,

* Journ. Northamptonshire Nat. Hist. Soc., vol. iii. pp. 197, 302; see also H. B. W., Explanation of Horizontal Section, Sheet 140, p. 7.

† Journ. Northamptonshire Nat. Hist. Soc., vol. iii., p. 189; see also Rep. Brit. Assoc. for 1891, p. 334.

‡ Proc. Cotteswold Club, vol. ii. p. 132; see also B. Thompson, Rep. Brit. Assoc. for 1891, p. 337; and G. Baker, History of Northampton, vol. i. p. 440.

§ Green, Geol. Banbury, p. 19.

showed the clays overlaid by Northampton Sands. Here about 8 feet of blue pyritic clay (with *Ammonites Holandrei*) was to be seen.

The clays have also been worked at Thenford Hill quarry, near the Camp and Windmill, between Thenford and Thorpe Mandeville. There Mr. Thompson obtained *Ammonites Holandrei, A. fibulatus, Nucula Hammeri, Leda ovum*, &c.; he regarded the clays as belonging to his Lower Leda-ovum beds. Similar beds were opened up in a clay-pit near Wappenham.

Over this area and to the north and north-east, the Upper Lias along its main outcrop, is overlaid by straggling outliers of Northampton Sands and Great Oolite, and the inclination of the ground corresponds generally with the dip of the strata, so that the streams draining into the Tove at Towcester flow over the dip-slope. This structure indeed prevails over those parts of Northamptonshire where the Upper Lias is developed, and Mr. Aveline observes that in many places "the brooks have merely removed the overlying sands and flow over the top beds of the clay, the toughness of which has a tendency to resist any further denudation."*

Outliers of Upper Lias, capped in most cases by Northampton Sands, occur to the north-west, at Wardington, Eydon, Arbury Hill, Staverton near Daventry, &c. I found evidence in the country between Little Preston and Fawsley Park, to show that the Basement Beds of the Upper Lias, extend over larger areas than are shown on the Geological Survey maps.†

The clays have been worked in many places for brick-making. The so-called "Unfossiliferous beds" having been opened up south-west of Weston, near Weedon Lois; between Morton Pinkeney and Sulgrave, between Farndon and Chipping Warden, between Everdon and Newnham (where the beds are worked beneath the Northampton Sands), at Upper Weedon, on the Weedon and Daventry Road near Daventry, in the railway-cuttings between Weedon and Daventry, and in a brickyard near Welton, where the clays have been preserved through a fault.‡

In the brickyards north of Eydon, the Middle Leda-ovum beds have been exposed, yielding *Ammonites fibulatus, Leda ovum*, &c. Many fossils were obtained here by Mr. Beesley, who remarks on their excellent preservation, the nacreous layer being present.§

Other sections have been exposed at Badby, to the E. of Everdon, and at Easton Neston near Towcester.

The main mass of the Upper Lias extends along the valley of of the Tove by Towcester to near Castlethorpe. The clay has been worked for brick-making south-east of Tiffield, between Blisworth and Towcester; at Kingthorn near Greens Norton, west of Towcester (Upper Leda-ovum beds); near Silverstone; Grafton Regis, and in other places.

The evidence obtained in pits near Deanshanger, shows that the Great Oolite is separated from the Upper Lias by about 20 feet of the Upper Estuarine Series and Northampton Sands. The

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* Geol. part of Northamptonshire, pp. 7, 8; and Geol. parts of Northamptonshire and Warwickshire, p. 7.

† H.B.W., Explanation of Horizontal Section, Sheet 140, p. 7.

‡ Thompson, Journ. Northamptonshire Nat. Hist. Soc., vol. iv. p. 16; Rep. Brit. Assoc. for 1891, p. 335.

§ See also Aveline and Trench, Geol. part of Northamptonshire, p. 8.

record of a well near Stony Stratford, however, gives no definite indication of these intervening strata: beneath the Great Oolite limestone, there is said to be 88 ft. of clay, and this probably includes the Upper Estuarine Series. (See p. 230.)

Inlying exposures of Upper Lias have been mapped at Stoke Goldington and Weston Underwood, between Olney and Newport Pagnel. I have examined the exposures, in company with Mr. A. C. G. Cameron, and we found no evidence of Upper Lias. The clays exhibit green and purple tints, like the Upper Estuarine Beds with which I think they should be grouped. The occurrence of "Nail-head spar" in the clay at Stoke Goldington brickyard might be taken as suggestive of Upper Lias; but bands of fibrous carbonate of lime or "beef," are not uncommon in the Upper Estuarine Beds, and the "cone-in-cone" structure of the nailhead spar, seems to be intimately connected with the "beef." It is, however, not unlikely that in this neighbourhood, as further westward, the Estuarine clays may, in places, rest directly on Upper Lias clay, for the Northampton Sands become much attenuated, and may not always be present.

Northwards the outcrop of the main mass of Upper Lias clay continues near Stowe-nine-churches and Blisworth by Northampton, and along the course of the Nen Valley and its tributaries.

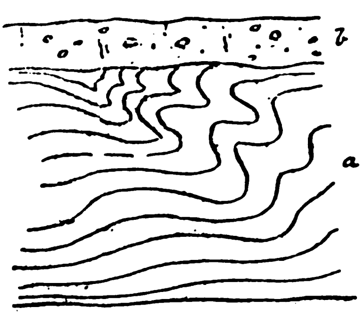
Stowe Brickyard east of Stowe-nine-churches, and south-west of Nether Heyford, showed the following section, to which I was conducted by Mr. Beeby Thompson:—

| | |
|---|---|
| Northampton Sands - | Brown ironstone. |
| Upper Lias - - | Grey and brown clay.<br>Blue slightly calcareous clay with calcareous nodules and "nail-head spar" (cone-in-cone). |

Small Gasteropods (*Cerithium armatum*), *Ammonites bifrons*, *A. fibulatus*, and *A. heterophyllus* are found in the clays, so that there is no evidence here of the highest stages of the Upper Lias, grouped by Mr. Thompson with the zone of *A. jurensis.*

FIG. 89.

*Section at a Brickyard near Gayton Wharf, Blisworth, Northamptonshire.*




*b.* Boulder Clay, 3 feet.
*a.* Upper Lias clay (much contorted), with ferruginous nodules and selenite. shown to depth of 15 feet.

Gayton brickyard, N.W. of Blisworth, showed the following section:—

| | | Ft. | In. |
|---|---|---|---|
| Boulder Clay | Blue and brown clay with scratched Chalk-stones, flints, &c. - - - 20 to | 25 | 0 |
| | (Even or gently undulating line.) | | |
| Upper Lias - | Blue slightly micaceous clay, with small nodules, and slightly calcareous concretionary seam, with *Ammonites bifrons*, *Nucula Hammeri*, &c. - - - | 25 | 0 |

Mr. Thompson records also *Ammonites Holandrei*, *A. serpentinus*, *Belemnites*, *Cerithium*, *Dentalium liassicum*, and *Inoceramus dubius*. Fossils are rare, and he considers the clay to belong to the "Unfossiliferous Beds."*

A lesser thickness of the same beds is exposed in another brickyard near Gayton wharf. The upper portion of the Upper Lias clay, beneath the Boulder Clay, is here seen to be very much contorted: a feature produced by Glacial action (see Fig. 89).

A boring at Gayton, was carried through about 8 feet of Drift and Upper Lias, 20 feet of Middle Lias rock-beds, and 553 feet of other beds of Middle and Lower Lias.†

The clays extend over a considerable area eastwards to Preston Deanery and Horton, and they have been worked for brick-making at Wooton.

The Upper Lias clay is well shown in brickyards at Northampton; in one known as the Vigo pit, on the southern side of the town, and in three pits near the Kingsthorpe Road on the northern outskirts of the town. The clays are exposed beneath a covering of the Basement-beds of the Northampton Sands, (ironstone, and ferruginous sandstone with nodules), 2 or 3 feet of which beds are exposed in places. Beneath, there is usually from 18 inches to 2 feet of grey shaly and ferruginous clay, which passes down into the ordinary blue clay with nodules of argillaceous limestone. At Vigo brickyard we see about 30 feet of clay. The fossils met with at these localities include the following:—

| | |
|---|---|
| Ammonites bifrons. | Nautilus astacoides. |
| —— communis. | Belemnites striolatus. |
| —— crassus. | —— Voltzi. |
| —— exaratus. | Cerithium. |
| —— heterophyllus. | Arca. |
| —— Holandrei. | Inoceramus dubius. |
| —— lythensis. | Leda ovum. |
| —— serpentinus. | Pleuromya costata. |

According to Mr. B. Thompson they indicate beds on the horizon of his Lower and Middle Leda-ovum Beds.

Lower down the Nen valley we find brickyards here and there, at Castle Ashby, north of the Midland railway-station, Wellingborough, and between Wellingborough and Finedon (Lower Leda beds); west of Wellingborough, and E. of the L. and N.W. Railway Station (Upper Leda Beds); Higham Ferrers (Lower Leda Beds); and Irthlingborough.‡

* Journ. Northampton Nat. Hist. Soc., vol. iv. p. 215.

† H. J. Eunson, Quart. Journ. Geol. Soc., vol. xl. p. 484; and B. Thompson, Middle Lias of Northamptonshire, p. 45.

‡ Paper in Journ. Northamptonshire Nat. Hist. Soc., vol. v. p. 62.

A well sunk at the Midland Station at Wellingborough, reached the Marlstone Rock-bed at a depth of 150 feet.

Mr. Thompson remarks that "The Lower *Leda-ovum* beds are nearly on a level with the river Nen for a good many miles eastward of Northampton, showing that the dip of the beds, in a north-easterly direction, is about equal to the fall of the river."

A short distance north-east of Thrapston, the Upper Lias is no longer visible, owing to coverings of Alluvium and River Gravel, but Prof. Judd states that it forms the bed of the Nen. It has been reached in deep wells, and he has observed it in places, near the Mill at Wadenhoe, at Oundle (where it was reached in a deep excavation by the side of the railway), at Cotterstock, and between Fotheringhay and Wansford.*

The tract of country northwards by Great Brington, Cottesbrook, Thornby, Clipston, and Oxenden Magna, is largely covered by Drift, which rests on the Upper Lias clays, but the Basement-beds extend further west than is shown on the Geological Survey map, having been exposed in railway-cuttings near Long Bucky, Crick, and Watford.

I again make use of Mr. Thompson's observations in recording the fossiliferous horizons.

The Lower and Middle Leda-beds have been exposed in the railway (Northampton to Rugby) north of Great Bringtou; and the Unfossiliferous Beds near Long Buckby, and again near Kelmarsh Station (Northampton and Market Harborough railway).

Brickyards have been opened at Long Buckby (U. Leda-beds), north of Holdenby, at Spratton (L. Leda-beds), west of Creaton, north of Hazlebeech, Naseby, near Oxenden Magna, and Arthingworth (Unfossiliferous Beds).†

Eastwards, the Upper Lias is covered by a large outlying mass of Lower Oolites extending from Northampton to Rothwell and Kettering; a mass disconnected further east by the valley of the Ise, a tributary of the Nen. Beds with *Leda ovum* have been worked in a brickyard north of Pitsford.

The following section, to which I was conducted by Mr. Thompson, is shown at Moulton Brickyard:—

| | | Ft. | In. |
|---|---|---|---|
| | Brown sandy soil. | | |
| Northampton Beds. | Yellow and brown sands, with films or layers of ironstone | 9 | 0 |
| | Thin beds of ferruginous sandstone. | | |
| | Ferruginous and calcareous sandstone (green-hearted) with rolled masses of argillaceous limestone | 6 | 0 |
| Upper Lias | Blue clay, sandy near top, with occasional septaria, and an Oyster-bed (limestone), 13 feet down | 15 | 0 |

At the base of the Northampton Beds there are rolled masses of argillaceous limestone containing *Ammonites bifrons*, derived from the Upper Lias, and bored. The Upper Lias yields *Ammonites bifrons*, *A. elegans*, *A. lythensis*, *A. lympharum*, *Belemnites*

* Geol. Rutland, p 86.

† See also Aveline and Howell, Geol. part of Leicestershire, p. 6.

‡ Journ. Northamptonshire Nat. Hist. Soc., vol. v. p. 66.

*levidensis*?, *B. subaduncatus*, *Gresslya donaciformis* *Trigonia northamptonensis*, and other species previously mentioned from the Upper *Leda-ovum* Beds (p. 273). The species of *Ostrea* are identified by Mr. Thompson as *O. sandalina* and *O. falciformis*.

The junction between the clay and overlying Northampton Beds, as noted by Mr. Thompson, is sharply defined, and the two formations appear comformable. Nevertheless the presence of the rolled masses of limestone on top of the clay, is suggestive of some local break; and if we regard the clay as belonging to the zone of *A. jurensis* as Mr. Thompson maintains, we must I think consider that the zone is only partially represented.*

At Kettering brickyard we find the Upper Lias clay, yielding many fine crystals of selenite. The beds have yielded *Ammonites bifrons*, but represent the unfossiliferous type of the series.

Several sections in the neighbourhood of Kettering are described by Mr. Thompson; in brickyards on the road leading towards Geddington, and on the Barton road, where he has obtained many fossils indicating the Upper *Leda-ovum* beds. Similar beds have been opened up between Great Harrowden and Isham, and the Unfossiliferous Beds have been worked at Orton, near Rothwell.

A boring in the Upper Lias between Kettering and Weekley appears to have reached the Marlstone at a depth of 44 feet.

The Oxenden Magna tunnel, on the London and North-Western Railway, leading from Market Harborough to Blisworth, passed through the Upper Lias clay, which is here thickly covered with Boulder Clay and other Drift. In the heaps of clay brought out from this cutting numerous Upper Lias fossils were collected by Prof. Judd, including the following:—†

| | |
|---|---|
| Ammonites serpentinus. | Ammonites communis. |
| —— falcifer. | —— Holandrei. |

*Northamptonshire (continued), Rutlandshire, and Leicestershire.*

Prof. Judd remarks that: "The great mass of Upper Lias in this area, which stretches from the north of Wymondham to south of Braybrook, and attains its greatest breadth between Tilton-on-the-Hill and Barrowden, is intersected by many winding valleys, which cut down deeply enough to expose the Middle Lias strata, sometimes forming inliers in the midst of the Upper Lias. On the other hand, the higher portions of the Upper Lias are capped by the beds of the Inferior Oolite, which form outliers, often of great size, scattered over the district of the Upper Lias. The valleys which breach the great escarpment of the Inferior Oolite, namely those of the rivers Gwash, Chater, and Welland, and their numerous tributaries, are cut down to the level of the Upper Lias, but the

* See also remarks by W. D. Crick, and J. F. Blake, Proc. Geol. Assoc., vol. xii. pp. 188, 189.

† Judd, Geol. Rutland, p. 81.

bottoms of these valleys being masked by superficial detritus, its beds are seldom exposed in them.

"A few small outliers of Upper Lias rising above the plateaux of the Marlstone Rock-bed also exist, as those of Great Bowden, Slawston, Staunton Mill, and Barleythorpe, and some of these are capped by beds of Inferior Oolite.

"The Upper Lias also forms a series of inliers in the midst of the Lower Oolite plateaux. Some of these form the bottoms of the valleys of the rivers which cut through these strata, which, as we shall show, thin out rapidly to the eastward, so that the Upper Lias is reached at comparatively small depths. This is the case in the parts of the valleys of the Glen, the Wansford Brook, and the Welland. In other cases, as at Stanion, Corby, and Helpstone brickyard, the Upper Lias is brought up by faults and exposed as inliers along the lines of certain small valleys."*

Sections of the Basement-beds have been noticed by Prof. Judd, and the subdivisions appear to be persistent in the area The paper-shales and "*Serpentinus* Beds" have been noticed at Slawston Hill, between Hallaton and Keythorpe, at Barleythorpe near Oakham, and at Edmondthorpe. I have seen the paper-shales in a cutting north of Wymondham, on the Bourn and Saxby railway; and a little further west about 12 feet of the shales, with a nodular band of Fish and Insect Limestone, were exposed. Crushed specimens of *Ammonites serpentinus* and *A. communis* occurred, but there was no evidence of the Transition Bed at the base of the Upper Lias. The beds rested on the Marlstone (see p. 238), and were covered in places by chalky Boulder Clay.

At Great Bowden and Market Harborough there are two small outliers of Upper Lias. The only important sections here are in the Market Harborough brickyard, opposite to the railway-station, and in the adjoining railway-cutting. Here we have the following section described by Prof. Judd:—

| | | | |
|---|---|---|---|
| | | Soil | 1 ft. |
| | | Boulder Clay | 2 to 3 ft. |
| Upper Lias. | Zone of *Amm. communis.* | Laminated blue clay weathering to a yellow colour, with *Ammonites communis* and *Belemnites compressus* | 1 to 4 ft. seen. |
| | Basement Beds | Hard, brown, ferruginous band of impure ironstone | 9 in. |
| | | Softer and more sandy bed full of,—<br>Ammonites serpentinus.<br>—— bifrons.<br>—— communis.<br>—— Holandrei.<br>Belemnites compressus, and other fossils | 9 in. |
| | | Hard, very ferruginous bed | 3 to 6 in. |
| | | Light-blue, laminated clays | 3 to 4 ft. |
| | | A thin vein of sandstone (very inconstant) | about 1 ft. |
| | | Light-blue, laminated clays | 5 ft. |
| Middle Lias | | Marlstone Rock-bed. | |

* Judd, Geol. Rutland, pp. 80, 81.

Here, as noticed by Prof. Judd, the Serpentinus-beds are ferruginous and much resemble the Marlstone, with which, in the absence of fossil-evidence, they might be confounded. At the Market Harborough brickyard, the "Fish and Insect limestones" were not detected. In the cutting just north of Market Harborough station, the Serpentinus-beds were well exposed, and were seen to be crowded with the usual fossils.* Pyrites was said to be plentiful in most of the wells at Great Bowden.†

Records of other sections in this neighbourhood are given by Prof. Judd. The Basement Beds of the Upper Lias were well exposed at Alexton, and a number of fossils were obtained. In the clays large masses of wood, converted into jet, are found. These, after being soaked in oil to prevent cracking, are used by the workmen and others for whetting razors. The limestone, which is hard and fissile, and of a blue colour weathering white, occurring sometimes in continuous bands and at other times in nodules, is carried to Tugby, where it is burnt for lime. Prof. Judd remarks that the Serpentinus-bed, which in many places is ferruginous, is at Alexton only very slightly coloured with oxide of iron.

Other sections showing the "Communis Beds" have been opened up near Neville Holt, where Prof. Judd obtained *Posidonomya Bronni;* also at Tugby brickyard, and in the railway-cuttings near Manton, and between Oakham and Ashwell.

The Unfossiliferous clays, which contain ironstone-nodules (decomposed iron-pyrites), have been exposed in a brickyard at Great Easton, in the cuttings and tunnel at Morcot (together with higher beds), in brickyards west of Oakham, and on Moor Hill, north of Hallaton. On Moor Hill the thickness of these clays must be 50 or 60 feet. At West Laund, near Tilton, there is a brickyard showing blue shaly clay, with many small nodules and selenite, apparently belonging to the Unfossiliferous division of the Upper Lias.

More interest attaches to the *Leda-ovum* Beds. They have been exposed in the brickyard at Stanion, where there is an inlier of Upper Lias; in brickyards between Rockingham and Cottingham, and at Gretton. Inliers also occur at Pipwell Abbey, Corby, &c.

A number of fossils are also recorded by Messrs. E. Wilson and W. D. Crick, from the grey clays in the East Norton railway-cutting; these include *Ammonites bifrons, A. communis, A. crassus, Belemnites subtenuis, Nucula Hammeri,* &c.‡

At a brickyard and tilery by Seaton railway-station, about 12 feet of grey or blue clay with small nodules of argillaceous limestone, covered by about 5 feet of brown Alluvial loam, were exposed: the clay yielded the following fossils some of which

* Geol. Rutland, p. 87.
† J. Woodward, Nat. Hist. Foss. Eng., Part I., p. 181.
‡ Geol. Mag., 1889, p. 298.

were noted by Mr. Thompson;* and others, collected by myself, were identified by Messrs. Newton and Sharman:—

| | |
|---|---|
| Ammonites bifrons. | Belemnites compressus. |
| —— communis. | Gasteropods. |
| —— cornucopiæ. | Leda ovum. |
| —— heterophyllus. | Nucula Hammeri. |
| —— Holandrei. | Trigonia pulchella. |
| —— serpentinus. | |

Prof. Judd mentions that in Keythorpe Park, a pond, dug in the lower part of the Upper Lias Clays, exhibited the richly fossiliferous bands, crowded with small *Ammonites*, &c., which characterize that part of the series (see Fig. 69, p. 235). He collected there the following fossils:—†

| | |
|---|---|
| Ammonites communis. (Very abundant.) | Ammonites bifrons. |
| —— annulatus. (Very abundant.) | Belemnites compressus. |
| —— Holandrei. | Leda ovum. |
| | Inoceramus dubius. |

The clays, and their junction with the Northampton Sands, were shown in brickyards at Uppingham; exposures were also to be seen in the railway-cuttings and brickyard near Manton.

Pilton brickyard, situated south of the railway, S.W. of North Luffenham, showed about 12 feet of blue clay overlaid by 6 feet of brown clay. Ferruginous nodules and septaria occur, and iron-pyrites and large crystals of selenite abound. Belemnites are more abundant towards the top of the beds. *Ammonites bifrons*, *Leda ovum*, and other fossils occur in the clays and in nodules.

The great Stamford and Helpstone fault also brings up the Upper Lias along the valley of the Wansford Brook, as pointed out by Prof. Judd. The beds were exposed at Thornhaugh, and a well was sunk there for upwards of 70 feet in blue clay without reaching the bottom of it.

Prof. Judd states that at Helpstone brickyard, north-west of Peterborough, there was an interesting exposure of the Upper Lias clay in a small inlier, which has been produced in consequence of the removal by denudation of the upper part of a small anticlinal, into which the beds are here bent. The beds consist of blue pyritous clays with much selenite, and are the highest of the series; they yield,—

| | |
|---|---|
| Ammonites bifrons. Abundant. | Belemnites compressus. |
| —— serpentinus. Rare. | Leda ovum. |

At Stamford the Upper Lias clay forms the bed of the river; in a deep excavation made at the gas-works Prof. Judd found *Ammonites bifrons*, *Belemnites compressus*, *Leda ovum*, &c. The same beds are met with in many wells in the southern part of Stamford, where the Stamford and Helpstone fault has thrown the Upper Lias clay to a much higher level. The Upper Lias

* Thompson, Journ. Northamptonsh. Nat. Hist. Soc., vol. iv. p. 16.
† Geol. Rutland, pp. 83, 84.

clay is dug at Lumby's Terra Cotta Works. A boring here is said to have passed through 140 feet of Upper Lias, and to have been carried to a depth of 500 feet in an attempt to find coal. The ornamental water of Burleigh Park rests on the Upper Lias Clay.*

### *Lincolnshire.*

While in Rutlandshire and East Leicestershire the Upper Lias is exposed over a considerable area, extending to the neigbourhood of Buckminster and Croxton Kerrial; northwards through Lincolnshire, the outcrop is narrower and more regular along the foot of the steep Oolitic escarpment.

Its thickness was proved to be 176 feet in a boring at Hambleton, S.E. of Oakham; and where sections have afforded evidence, the main divisions recognized further south have been followed.

The Basement Beds have been exposed above the Marlstone at Scalford, where shales with flattened nodules (Fish and Insect limestones) have been observed, having a thickness of over 20 feet, in a brickyard. The usual fossils were obtained, such as *Ammonites communis, A. serpentinus, Inoceramus dubius,* and *Posidonomya Bronni.* The beds were also exposed in the railway-cutting east of Scalford.

South of Grantham the Upper Lias extends a long distance along the base of the valley of the Witham river to North Witham, and follows its tributaries westwards, connecting with the main outcrop near Skillington, and thus isolating a large mass of the Lower Oolites.

The Basement Beds were observed by Prof. Morris in excavations between Grantham and Little Ponton, by Mr. Dalton in the railway-cutting between Fulbeck and Leadenham, and by Mr. Ussher in a brickyard N.E. of Welbourn.

A brickyard south of Grantham railway-station, showed about 40 feet of blue clay and shale with septaria and selenite; with débris of sand and ironstone (Northampton Beds) on top.

From this brickyard the following fossils were collected at different times by Messrs. R. Gibbs and J. Rhodes:—†

| | |
|---|---|
| Ammonites annulatus. | Ammonites serpentinus. |
| —— bifrons. | Belemnites. |
| —— communis. | Nautilus. |
| —— crassus. | Inoceramus dubius. |
| —— falcifer. | Leda ovum. |
| —— fibulatus. | Posidonomya Bronni. |
| —— heterophyllus. | Discina reflexa, &c. |

The beds were also exposed in a brickyard near Stoke Rochford.

* Judd, Geol. Rutland, p. 86.
† Geol. S.W. Lincolnshire, pp. 44, 130.

The Upper Lias clay (Leda-ovum beds) was exposed in a brickyard at Stonesby, east of Waltham-on-the-Wolds, where the section was noted as follows, by Mr. Jukes-Browne:—*

| | | Ft. | In. |
|---|---|---|---|
| Northampton Beds | Red ferruginous sandstone - - - | 12 | 0 |
| Upper Lias - | Pale grey micaceous clay with ferruginous concretions, passing down into dark blue shaly clay with selenite and iron-pyrites - | 19 | 0 |

The same beds were cut through by the Great Northern railway south of Grantham, where they were described by Prof. Morris.†

At Lincoln the Upper Lias is about 100 feet thick, and the beds no doubt extend underground throughout the eastern part of Lincolnshire. The deep boring at Woodhall Spa, reached the Lias at a depth of 640 feet, according to Mr. Jukes-Browne's estimates.‡ To what distance the Lias extends beneath the Fenland area, we have no evidence to show, but we know that it dies out to the south-east before we reach Harwich. Beneath the Oolites at Peterborough, upwards of 300 feet of Lias (chiefly clay) was proved in a boring at the Great Northern Railway works, New England.

The Upper Lias is well shown in several brickyards in the escarpment north and south of Lincoln, and the beds have been studied in much detail by Mr. W. D. Carr and Mr. W. H. Dalton.

The principal sections are those on the south, known as Best's Brickyard, or the Cross Cliff Brickworks, at Bracebridge; and on the north, Swan's Brickyard or the West Cliff Brickworks.§ A complete section of the Upper Lias, showing about 100 feet of strata, has been exposed at Best's brickyard, and about 60 feet of the upper portion of the clays was shown at Swan's brickyard. In both cases the clays were surmounted by the Basement-beds of the Inferior Oolite, which at Swan's pit comprised the following strata:—

| | | Ft. | In. |
|---|---|---|---|
| Lincolnshire Limestone. | Flaggy and comminuted shelly oolite - | 2 | 0 |
| Northampton Beds. | Sandy beds and ironstone with small scattered nodules, and nodular bed at base | 4 | 0 |

The mass of the Upper Lias below, consisted of dark shaly clay, with rusty joints and ferruginous clays near the top, and at intervals lower down, there were layers of septaria and nodules of argillaceous limestone (cement-stone). Excepting in the higher beds, fossils are abundant, and we have no indication of the Unfossiliferous zone of Northamptonshire. Specimens of

* Geol. S.W. Lincolnshire, p. 44.
† Quart. Journ. Geol. Soc., vol. ix. p. 324.
‡ Geol. Lincoln, p. 208.
§ In 1889 these brickyards together with those belonging to the Bracebridge Brick Co. and the Lincoln Brick Co., were amalgamated under the Lincoln Brick Co.

*Ammonites bifrons, A. communis, A. fibulatus, A. heterophyllus, A. serpentinus*, together with *Belemnites subtenuis, B. vulgaris*, and *Nautilus terebratus*, may be obtained in abundance.

The Upper Lias was subdivided as follows by Mr. Dalton:—*

| | | Ft. | In. |
|---|---|---|---|
| Zone of *Ammonites bifrons*. | Shales with ferruginous and calcareous nodules (cement-stones) - about | 38 | 0 |
| Zone of *A. communis*. | Shales with comminuted shells: yielding *Ammonites communis*, Gasteropods, &c., and with at top a Nucula- or Trigonia- bed, with *Nucula Hammeri* and *Trigonia pulchella* - - - - - | 8 | 0 |
| Zone of *A. serpentinus* and *A. heterophyllus*. | Shales with septaria and shelly beds yielding *A. heterophyllus, A. serpentinus, Belemnites subtenuis;* and with Lucina-bed at top - - - - 40 0 to | 45 | 0 |
| Zone of *A. annulatus*. | Shales with two or three bands of argillaceous limestone (Fish and Insect Limestones): *Ammonites annulatus, A. communis, Inoceramus dubius*, - - about | 8 | 0 |

The lowest beds (here grouped as the zone of *A. annulatus*), are evidently equivalent to the Basement Beds of other localities; while the mass of the higher strata evidently belongs to the beds elsewhere grouped as the zone of *A. communis*.

The highest division has yielded but few fossils, and it cannot therefore be compared with the beds which Mr. Beeby Thompson has grouped in the zone of *A. jurensis*. The nodular bed at the base of the Inferior Oolite series, is suggestive of a break, and compares well with the evidence we have throughout the country from the neighbourhood of Banbury northwards. Mr. Ussher indeed is disinclined to regard the junction as unconformable, but it appears most reasonable to conclude with Mr. Dalton, that there is evidence generally of transgressive overlap of the Inferior Oolite.

The Basement Beds (clays and shaly limestones), were exposed in a brickyard north-east of Navenby station, and there Mr. Ussher procured a fragment of an Ammonite, identified as *A. striatulus?* by Messrs. Sharman and Newton. Such an occurrence accords with the evidence obtained in Dorsetshire.† (See p. 255.) The higher beds of Upper Lias clay were seen near Coleby. Northwards by Brattleby and Harpswell‡ there are few exposures of Upper Lias; and onwards by Kirton Lindsey and Santon to Winteringham, the evidence shows that the thickness is considerably diminished.

A shaft sunk at Appleby indicates about 70 feet of Upper Lias, and perhaps a similar thickness was passed through at Brigg, but other borings tend to show that the thickness may be much less, and according to Mr. Ussher little over 25 feet in places§: an

* Geol. Lincoln, p. 33. See also W. D. Carr, Geol. Mag. 1883, p. 164.
† Geol. Lincoln, p. 180.
‡ See Memoirs of W. Smith, p. 96.
§ Ussher, Geol. Lincoln, pp. 55, 56, 211.

attenuation not inconsistent with the view of the overlap of the Inferior Oolite series.

From the railway-cutting north of Kirton Lindsey, *Ammonites communis, A. semicelatus,* and other fossils were obtained. The clays have been worked for brick-making near Kirton railway-station. In a well at Roxby Grange, dark grey shales with *A. serpentinus,* were found beneath the Basement-beds of the Inferior Oolite: here again the evidence suggests unconformable overlap of the newer beds.

From this region we pass into Yorkshire, and the beds in that region are described by Mr. Fox-Strangways.

It is possible (as mentioned p. 244) that traces of Upper Lias may be preserved at Prees in Shropshire, but nowhere else in England or Wales have we any reason to suspect the presence of the formation in outliers far away from the main outcrop.

# CHAPTER XI.

## ECONOMIC GEOLOGY.

### *Lime and Cement.*

THE Lower Lias limestones have long been celebrated for their hydraulic cement and Blue Lias lime.

Many of the layers or nodules of stone furnish naturally the ingredients required for "water-lime" or hydraulic cement, and they are known as cement-stones or cement-beds: thus the products are spoken of as Natural cements, in distinction from the Artificial Portland cement, made often by mixing materials obtained from different strata and localities.

Great part, however, of the cement made from the Lower Lias is produced by a mixture of a number of layers of stone and shale or clay; a plan necessary on account of the limited quantities of the good cement-beds, and necessary also in order to ensure uniformity in the products. Not only are the layers different in character, but each individual layer is liable to variation. Some of the best cement-beds are dark shaly limestones, others are nodular masses of argillaceous limestone. Layers that contain pyrites must be rejected.

At the base of the Lower Lias generally throughout England, there are alternate bands of more or less argillaceous limestone and shale or clay, but the quality of the strata and the thickness of the beds adapted for the preparation of lime and cement, vary considerably. In some localities the limestone-bands are comparatively few, in other cases we have a mass of limestones and shales attaining a thickness of 200 feet. Beds on different stratigraphical horizons are worked in different localities, though in all cases, as regards the Lower Lias, they belong to the lower zones of *Ammonites planorbis*, *A. angulatus*, and *A. Bucklandi*.

So called "Blue Lias Lime" is made from strata of Inferior Oolite age at Kirton Lindsey, and from other formations; but in such cases the use of this name for trade-purposes is unfortunate, although the lime produced may be of first-rate quality.

True Blue Lias lime and cement are prepared from material obtained at Aberthaw, Bridgend, Stormy Cement Works near Bridgend, Lliswerry, Watchet, Dunball near Bridgwater, Langport, Lyme Regis, Pylle, Shepton Mallet, Weston near Bath, Wilmcote, Harbury, Stockton, Rugby, Barrow-on-Soar, Evington, Barnstone, Granby, Elton, Cotham, and Coddington; and at some other localities mentioned previously.

At several of these localities the lime has been long celebrated. J. Woodward, in 1729, speaks of Ammonites "Found in a

Quarry, the most famous in *England*, for Limestone; it being very hard, and making excellent Lime, at *Barrow* in Leicestershire."*

Aberthaw, on the Glamorganshire coast, and Lyme Regis have been for long particularly favoured localities for hydraulic lime, as the material can be readily shipped in the raw state. At Aberthaw the limestone was taken away in the form of large beach-pebbles, and burnt at the localities where the lime was wanted. Smeaton ascertained that the Lias lime made a harder mortar under water than any other lime with which he was acquainted. When he built the Eddystone Lighthouse he sent round the Land's End to Aberthaw for limestone, whereas, as De la Beche has remarked, he could have procured equally good material from Lyme Regis.†

The character of the strata at the several localities has been already described, and it will be necessary here only to allude to the products. In some localities only lime is made, in others various kinds of hydraulic cement are also prepared.

The lime obtained from the Lias is hydraulic in character: and it is stronger and also darker in colour (owing to the clay and iron), than the "fat lime" obtained from purer limestones. Thus Lias lime is sometimes spoken of as "Brown lime," in distinction from the "White lime" or "Marble lime," made from the rich Carboniferous or Devonian limestones. Owing to its strong and binding character, the Lias lime is not, as a rule, adapted for agricultural purposes, though it is sometimes put on light lands, the "Marble lime" being used for heavy soils.

There are, however, in some localities, layers of Blue lias that contain a very large percentage of carbonate of lime, and that when calcined, furnish a good agricultural lime. Good hydraulic limestone should have not less than 15 per cent. of clay.

Lime is made from the limestone, which is burnt in masses as quarried, so that some of the coal-ash becomes commingled with it.

The lime is supplied in the form of Lump lime and Ground lime. The Lump lime is used for mortar, being mixed (under a mill) with ashes, sand, pounded tile, brick-rubble, &c. It is also used for stucco, being mixed with clean sharp sand, in the proportion of ¼ best lime and ¾ sand.

The Ground lime, which has already been ground in a mill, is used for concrete foundations, and also for brick-work and stone-walling: it is especially valuable for reservoirs and water-works, for docks and sea-walls, tunnels, &c. For concrete 1 portion of lime to 6 or 8 of gravel is generally used.

If ground so as to facilitate the slaking of every particle, and used immediately, the hydraulic limes produce a mortar which becomes much harder and far more durable than that of the rich limes. Blue Lias lime is now very often specified by Architects and Engineers for use in Mortar, as well as in Concrete; because the Mortar made from rich limes is not suited for damp situations, and when very dry it becomes friable.

Lump lime is made sometimes from limestone containing a larger percentage of lime than that used for the Ground lime; the latter is made from beds richer in alumina, and soluble silica.

The Cement is prepared from the limestone and clay. The stone is broken, usually by a stone-crusher, and ground by millstones. The powder is then mixed with clay, the proportions being weighed. The materials are mixed with water in mixing-boxes or pug-mills. The wet masses are taken out in lumps, and sometimes roughly shaped into the form of bricks, and dried over a heated floor. The material is then put into the kiln; and afterwards

* Nat. Hist. Foss. England, vol. i. p. 26

† Report on the Geology of Cornwall, etc., p. 507.

crushed, ground in a mill, and passed through fine sieves. It is then ready to be put into barrels or sacks for delivery.

In some instances "Portland cement" is manufactured from specially selected Lias stone; and this is said to set more quickly than the ordinary Blue Lias cement. Particular varieties are also supplied to the trade under the names of Roman, Bath, and Lias cements, some setting more rapidly than others, and possessing different degrees of tenacity.

The essential constituents in cement are:—Lime 45 to 65 per cent., clay 20 to 30 per cent., and oxide of iron 3 to 14 per cent. In the preparation of the cement, it is necessary in some cases to add a certain amount of oxide of iron, when the stone and shale are deficient in it.

The hydraulic powers of the cement are dependent on the amount of soluble silica; a double silicate of lime and alumina being formed during the preparation of the material.

Selenitic cement is made in some places. This is formed from a mixture of calcined gypsum, sand, and hydraulic lime. It is used for mortar, plastering on lath-work, stucco and concrete.*

### *Artificial Stone.*

The Blue Lias Cement is employed in the manufacture of some of the artificial paving-slabs, sinks, and troughs. Thus chips of Mount Sorrel stone are embedded in "portland cement" and shaped in moulds. Afterwards, when solidified, they are steeped in a "silica solution," formed of silicate of soda, and in this the slabs remain immersed for seven or eight weeks. This is done at Barrow-on-Soar for the manufacture of Granolithic pavement. "Victoria Stone" is similarly made from Groby rock. At Rugby, concrete is formed with cement and chips from stone-quarries, and fashioned into window-sills, coping-stones, paving-slabs, &c. The silica solution is of great service in filling up all the interstitial spaces in the concrete.

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A. Analysis by Mr. John Spiller (1870). Communicated by Mr. Wm. Porter.

B. Analysis by Mr. Henry T. Jones, F.I.C. (1888). Communicated by Mr. Wm. Porter.

C. Analysis by Messrs. Holland and Phillips (1883). Communicated by Messrs. John Davies and Company.

D. P. Analyses by Mr. W. Harry Stanger (1888). Communicated by Messrs. Greaves, Bull, and Lakin.

E. Analysis by Mr. Charles Tookey (1858).

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G. H. Communicated by Mr. C. Hall.

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K. R. Communicated by Mr. H. Parry.

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M. Analysis published by Mr. H. Reid.

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O. Analysis published by Mr. H. Reid, Manufacture of Portland Cement, 1877, p. 56; *see also* R. Phillips, Ann. Phil. ser. 2, vol. viii., 1824, p. 72; and A. Voelcker, Journ. Bath and W. of Eng. Soc., ser. 2, vol. vi., p. 228.

P. Analysis published by Mr. H. Reid.

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* See also John Grant, Proc. Inst. C.E., vol. lxii. p. 98; and Notes on Building Construction, Part III., ed. 2 (Rivingtons), 1889, p. 145.

## Table of Analyses of Limes and Cements.

| Analyses of Limes and Cements. | Lyme Regis Cement. | Lyme Regis Lime. | Lliswerry Cement. | Harbury Cement. | Stockton Lime. | Stockton Lime. | Rugby Lime. | Rugby Portland Cement. | Barrow-on-Soar Lime. | Barnstone Lime. | Kirton-in-Lindsey Lime. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | A. | B. | C. | D. | E. | F. | G. | H. | I. | J. | K. |
| Insoluble residue | Traces. | 1·17 | — | } 20·59 | { 2·90 | — | — | — | 1·03 | — | — |
| Silica | 26·6 | 13·29 | 16·04 | | 14·06 | 19·07 | 19·25 | 21·50 | 12·43 | 20·61 | 14·61 |
| Ferric oxide | } 22·0 | { 4·25 | 7·81 | } 18·86 | { 2·38 | 4·05 | 4·36 | 3·21 | 2·90 | 4·01 | 2·63 |
| Alumina | | 5·95 | — | | 4·78 | 6·46 | 4·60 | 9·43 | 4·65 | 6·98 | 3·27 |
| Phosphoric acid | — | — | — | — | 0·22 | — | — | — | Trace. | — | — |
| Sulphuric acid | 1·7 | 1·97 | 1·22 | 2·03 | 1·12 | — | — | — | 1·77 | 1·94 | 2·80 |
| Carbonic acid | Traces. | 3·26 | 6·23 | ·63 | 3·00 | — | — | — | 1·06 | ·46 | 0·93 |
| Lime | 46·7 | 67·22 | 64·32 | 54·52 | 62·20 | 68·09 | 64·37 | 62·70 | 72·98 | 59·61 | 71·76 |
| Magnesia | 2·5 | 0·94 | 1·49 | 2·18 | 1·82 | — | 2·30 | ·68 | 2·48 | 2·25 | 1·30 |
| Potash | — | — | 1·16 | — | 0·81 | — | — | — | ·64 | — | — |
| Soda | — | — | 0·37 | — | 0·14 | — | — | — | — | — | — |
| Organic matter | — | — | 1·36 | — | — | — | — | — | — | — | — |
| Sulphate of lime | — | — | — | — | — | — | 1·29 | 2·07 | — | — | — |
| Manganese oxide | — | — | — | — | 0·12 | — | — | — | Trace. | — | — |
| Alkalies, water and loss | — | 1·95 | — | 1·19 | — | 2·33 | — | ·41 | — | 4·14 | 2·70 |
| Carbonate of lime | — | — | — | — | — | — | 3·83 | — | — | — | — |
| Water | 0·5 | — | — | — | 6·40 | — | — | — | — | — | — |
| | 100·0 | 100·0 | 100·00 | 100·00 | 99·95 | 100·00 | 100·00 | 100·00 | 99·94 | 100·00 | 100·00 |

## TABLE OF ANALYSES OF LIMESTONES.

| Analyses of Limestones. | Pylle, Somerset. | Lyme Regis. | Lliswerry. | Aberthaw. | Bridgend. | Harbury. | Kirton-in-Lindsey. |
|---|---|---|---|---|---|---|---|
| | L. | M. | N. | O. | P. | Q. | R. |
| Carbonate of lime | 84·55 | 79·2 | 78·45 | 86·0 | 76·0 | 76·60 | 80·00 |
| Carbonate of magnesia | — | — | — | 2·0 | 4·0 | 1·15 | 0·31 |
| Alumina | 2·33 | 17·3 | 6·25 | 1·0 | 2·0 | 16·09 | 3·30 |
| Silica | 11·15 | | 9·35 | 8·0 | 10·0 | | 12·70 |
| Oxide of iron | Traces. | — | Trace. | 2·0 | 4·0 | 1·00 | 0·75 |
| Alkaline salts, &c. | — | — | — | — | — | 3·42 | 1·94 |
| Moisture | 1·97 | 3·5 | 5·70 | 1·0 | 4·0 | 1·74 | 0·16 |
| Organic matter and loss | | | | | | | 0·84 |
| | 100·00 | 100·0 | 99·75 | 100·0 | 100·0 | 100·00 | 100·00 |

In addition to the names just mentioned, I am indebted to Messrs. John Board and Company, of Dunball; to Mr. H. J. Harding, of the firm of Messrs. Greaves, Bull, and Lakin, of Wilmcote, Harbury, and Stockton; to Messrs. Haycraft and Company, of Lyme Regis; and to Messrs. Charles Nelson and Company, of Stockton, near Rugby.

Referring to his analysis of the Stockton lime, Mr. C. Tookey remarks that the lime had probably been exposed to the air since burning, as shown by the amount of water and carbonic acid. He says that the sulphuric acid may, in some limes and cements, result from the iron-pyrites in the coal used for burning: but in this instance sulphuric acid was found to be present in two examples of the limestone from which the lime is produced.

The Marlstone as well as the Lower Lias limestone, is occasionally burnt for lime for agricultural purposes.

At Alexton, north-west of Rockingham, the basement-limestones of the Upper Lias are dug and sent to Tugby, where they are burnt, and they make an hydraulic lime said to be equal to that of Barrow-on-Soar.*

*Building Stones.*

The Lias nowhere yields any building-stones that have been extensively used far from the localities where such material can be quarried. In the stone-districts the houses are usually constructed of the Lias limestones, and the older cottages have thatched roofs; but over the greater part of the Lias area, bricks are the chief building-materials, and the towns like Gloucester, Evesham, Stratford-on-Avon, Northampton, Grantham and Lincoln, are constructed for the most part of brick, with red-tiled or slated roofs.

The Lower Lias limestones are locally employed for building-purposes, but as a rule the stone is not very durable, and much of it shivers with the frost. "When taken from the sea-side, as near Lyme Regis, where it has become impregnated with saline water, it is notoriously bad."† The flues of houses built of Lias limestone are usually constructed of brick.

The most durable stone in the Lower Lias is that of Sutton, near Bridgend in Glamorganshire. This is a pale granular and crystalline limestone, altogether different in texture from the ordinary beds of the Lower Lias. It furnishes a freestone that is used for building, while the top beds are employed for walling. It was formerly used in the construction of some of the old Welsh castles, in Neath Abbey, &c.

Beds somewhat similar to the Sutton Stone are quarried on the north side of Shepton Mallet. Again at Downside, near Wrington, there is a stone (referred to as Brockley Down Limestone) which presents some resemblances to the Doulting stone (Inferior Oolite), but by no means possesses so firm a texture. Analysis shows 4·8 per cent. of silica.‡

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* Judd, Geol. Rutland, p. 79.

† De la Beche, Report, p. 488.

‡ See Analysis by T. Ransome and B. Cooper, Mem. Geol. Survey, vol. ii. Part II. p. 687.

The tougher and more crystalline limestones of the Blue Lias, furnish the better building-stones; the banded and fissile and more earthy limestones being unsuitable.

The best paving-stones are obtained from the lower portions of the limestone-series, usually the zone of *Ammonites planorbis;* for these strata as a rule are more evenly-bedded than the limestones at higher stages.

At Street near Glastonbury and at King Weston and Keinton Mandefield, good paving-stones (paviours) are obtained, slabs 12 feet square and even larger are sometimes raised. Some of the beds at Keinton have been tried for lithographic stone. Curb stones and building-blocks are also procured, and slabs are employed for garden-fences, imparting however a dull aspect to the cottages, as may be seen at Street, Queen Camel, Marston, and other villages. Troughs, steps, and tomb-stones are also shaped from particular layers of stone. (See p. 77.)

Stone-walls are a common feature in the district of the Lias limestones, and the enclosures as a rule are small.

In the neighbourhood of Street, when the stone has been worked out, the quarries are filled in with the "rubbish" (shale and broken limestone), and the ground is then planted with apple-trees. In such sheltered and well-drained situations, orchards are found to flourish.

Building-blocks have been obtained at Saltford and Keynsham, and the stone has been employed in some of the churches of the district, and in Great Western Railway works. Thus the railway-station at Keynsham is built of the Keynsham stone (Blue lias). Nevertheless, as remarked by Prof. Lloyd Morgan," wherever Lias has been used, there will you find the abundant signs of decay."*

In Worcestershire and Warwickshire the basement-beds of the Lower Lias yield good paving-stone, also stone that is employed for steps, and that has at times been polished for mantel-pieces, &c. Slabs from 1 to 8 inches thick, and 30 square feet in superficial area, are obtained. None of the beds afford any durable building-stone, as the rock exfoliates under the influence of the weather.

Bluish-grey and buff or pale-grey slabs are obtained at Wilmcote: and these are useful for inside work in halls, &c., as the stone is smooth and even-grained. White house-paving-stone is obtained from a layer known as the "Whites," and when rubbed and cut into squares, it forms a very smooth floor: it has been used in the Houses of Parliament and in the New Law Courts.

Rougher slabs, suitable for the floors of farmhouse kitchens and barns, have also been obtained in many localities: as at Hasler Hill near Evesham, Binton near Bidford, &c.

It is stated that the Wilmcote Stone can be rubbed to a face sufficiently smooth to be used for lithographic purposes; and, it was mentioned by Strickland that "Experiments, partly suc-

* Proc. Bristol Nat. Soc., ser. 2, vol. v., p. 95.

cessful, have been made to apply the Hasler stone to lithography. It is well adapted for the lithographic *ink*, but is not suited for *crayons*."*

Some of the Lower Lias limestones at Queen Camel, near Sparkford, have yielded thin stone-tiles that were used for roofing; and beds near Burley Dam in Shropshire were at one time quarried for similar purposes. (See p. 181.)

The Marlstone Rock-bed in Somersetshire is used for rough building-purposes, but the beds as a rule are too thin in this region to be of much service except as road-metal. The development of rock-beds is indeed uncertain. Here and there in Gloucestershire, as at Stinchcombe and Dursley, the stone-beds are quarried for rough building-purposes (walls, &c.). The beds are also locally used for building-stone in various parts of Northamptonshire and in Rutlandshire.

The best of the Lias building-stones is that obtained from the Middle Lias of Edge Hill, known generally as the Hornton Stone. In this neighbourhood it is extensively quarried, and the green and brown varieties form a pleasing contrast in the buildings: the Catherine Wheel Inn, and the door-way of the Mechanics' Institute, at Banbury are good examples of the material. This stone was used in most of the old churches and buildings of the district, and when well-selected it has proved a fairly durable material. Much of the stone however does not appear fitted to withstand great weights, being apt to crack and thus to be more readily acted upon by the weather. As a rule the corner stones of the better class of buildings are formed of Oolitic freestone. Not only are blocks of the Hornton Stone obtained for building-purposes, but slabs are dressed for paving; and stone-steps, sinks, and tomb-stones are made.

Thin flaggy beds in the Marlstone at Chacombe near Banbury have been employed as stone-tiles. A dark stone from Byfield (probably Marlstone), was formerly worked and cut into squares for paving halls.†

It is noticeable that the best building-stone in the Marlstone occurs where the beds have no covering of Upper Lias clay.

The fact that the brown weathered portions of the Marlstone are generally employed for building in preference to the green unweathered rock, has been commented upon by Mr. Beeby Thompson. It is true that the brown rock is more easily worked; but the green rock not having undergone those chemical changes produced by atmospheric influences, he considers that the naturally seasoned rock is more likely to prove durable.‡ This is likewise the case with many of the Oolitic freestones.

### *Local Names of Stone-beds.*

In most Lias quarries the limestone-bands have different names applied to them by the quarrymen. Most of these are given from

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* Memoirs of H. E. Strickland, p. 84.

† J. Morton, Nat. Hist. Northamptonshire, 1705, pp. 108, 126.

‡ Middle Lias of Northamptonshire, p. 67.

the thickness, colour or uses of the bed, or from some other local peculiarity, as at Rugby where we find the Knotty Rock, Big Jumbler, Cat Heads, &c. Other local names in use at Lyme Regis, Street, &c., have been already noted.

*Dew Stone.*—The term Dew or Jew Stone is most likely derived from the Celtic *Dhu* or *Dubh*, meaning black. Thus the Clee Hill basalt is known as Dhu stone, and it is quite likely that the name has been used by quarrymen for dark-coloured rocks in various parts of the country; but it has to a great extent lost its original meaning, as the "Dew stone" in many places is a brown or buff limestone.

*Bastard Lias.*—An inferior or decomposed stone.
*Burrs.*—A term (meaning rough) that has been applied to Blue lias stone, used for building; at Axminster (Buckland, Trans. Geol. Soc., ser. 2, vol. i. p. 99); and to other rocks, in the Purbeck strata, &c.
*Clog* (derived perhaps from the Celtic *clog* or *cloch*, a stone) is applied to certain hard limestones of the Lower Lias, employed for building.
*Firestone.*—Applied to tough coarse-grained Lias limestones that are sometimes used "for forming the arch-work of lime pits," Axminster (Buckland, *op. cit.*) At Lyme Regis, some of the Firestone-nodules have been shaped into fire-balls.
*Pendle.*—Applied to shaly limestone at Wilmcote; the name is also used for *fissile* beds in the Stonesfield Slate and Purbeck Beds.
*Sizes.*—Applied to layers of Blue Lias limestone, in some cases to beds that are useful for paving: the term usually has reference to the thickness of the beds.

### *Road Metal.*

In former days it was usual to mend the roads, wherever possible, from material obtained in each parish. Consequently there were far more quarries in the strata than is the case now-a-days, when materials are brought from a distance. (See p. 12.)

The limestones of the Lower Lias, and the Marlstone, have yielded much road-metal, and the stone is still employed in many places.

The Lower Lias limestone is not a good material, as it grinds readily to powder, forming in dry weather a thick white dust, and in wet weather sticky mud. Sandy and ferruginous limestones met with in Leicestershire and Lincolnshire have also been used for road-metal.

The Marlstone in many places furnishes a more durable material, especially in the neighbourhood of Yeovil and Ilminster, in Somerset. There the Rock-bed, sometimes little more than a foot in thickness, is much in demand: for it is a tough and durable stone. Near Dursley, in Gloucestershire, and in the Midland counties, the Marlstone (both ironstone, and earthy limestone) is also used, but chiefly now-a-days for mending the by-roads.

Bands of calcareous sandstone or of shelly limestone in the lower part of the Middle Lias have also been used for road-metal. These lower beds have thus been worked at Overthorpe, near Warkworth, and at Twyford lane, near Adderbury.

## *Marble.*

Some of the denser limestones of the Lower Lias have been polished for local use as chimney-pieces, &c. In the Museum of Practical Geology there are polished specimens of Lias limestone from Radstock and Shepton Mallet. The stone is still occasionally polished at Street (see p. 81), and it was formerly so used at Binton and Grafton in Warwickshire.

Of ornamental stones the Marston Marble, or Ammonite Marble of Marston Magna near Yeovil, is familiar in Museums. As previously stated (p. 84), some large nodular masses of this limestone have been obtained, from which various small polished specimens, and slabs for tables have been prepared. The stone is now scarce, as no fresh material has been found for many years.

Small masses of somewhat similar Ammonite Marble have been obtained from the neighbourhoods of Ilminster and Lyme Regis.

The Banbury Marble, which occurs in the upper part of the Lower Lias, at Banbury, is a shelly limestone, that has locally been used to a small extent for chimney-pieces. At Watford, N.E. of Daventry, a bed on a similar horizon, has been dug and polished for marble. (See also p. 167.)

## *Miscellaneous uses of Fossils.*

Ammonites from the Lower Lias of Lyme Legis are cut and polished for sale. Some of the smaller specimens are mounted for brooches and other ornaments. Specimens from this locality are also sent to Whitby for sale.

Among the curious uses to which fossils have been put, it may be mentioned that Gryphites have in Scotland been valued as Amulets, and to them have been attributed the virtues of curing pains in the joints.*

In the parish of Awre, in Gloucestershire, the *Gryphæa arcuata* was used as a medicine for cattle; the fossils were beaten to a powder, which was mixed with whey, and the compound was then applied as a drench.† In the same county Belemnites were used to cure watery affections of the eyes of the horse; in these cases the fossil was pulverized, and the powder was then blown into the eyes of the animal.‡

## *Brick and Tile Clays.*

The Lias Clays at various horizons are employed in the manufacture of bricks, tiles, and drain-pipes; and also in some places for flower-pots, chimney-pots, &c.

The articles manufactured are mostly red, but occasionally red and yellow: the colour depending on the composition of the clay, and on the temperature to which the articles have been subjected.

The clays are variable, and therefore experiment alone can determine their fitness in different districts for brick- or tile-making. The presence of much carbonaceous matter is calculated to discolour the bricks. A small amount of calcareous matter is

* Pennant, Tour to Hebrides, p. 232.

† Rev. C. P. Wilton, Quart. Journ. Sci. Lit. and Arts, ser. 2, 1830, p. 69.

‡ J. Woodward, Nat. Hist. Fossils, England, 1729, Part I., p. 109.

desirable; as lime is said to diminish the contraction of the raw brick in drying, and it acts as a flux in burning, causing the grains of silica to fuse, and thus binding the particles of the brick together.* This calcareous matter must be in a finely divided state.

Some of the clays are too calcareous, more especially those that alternate with the limestones in the basement portions of the Lower Lias. Thus at the Rugby quarries, the clays and shales contain about 30 per cent. of carbonate of lime, and are therefore unsuitable for the manufacture of bricks; but at Hill Moreton not far off the clays at a higher horizon, furnish a superior brick. In other cases shells and small calcareous nodules or "race," the presence of which would be apt to "blow" the bricks, render the clays unsuitable. Iron-pyrites again is objectionable, and must be removed from the clays.

In many localities the Lower Lias clays, above the mass of the stone-beds, are employed for brick-making and other purposes. Thus at Lyme Regis, bricks, tiles and pipes are manufactured, and this is the case at intervals throughout the country to Lincolnshire. Some of the best bricks are made at Hill Moreton near Rugby. Their red colour is said to become brighter after use and exposure in buildings. They keep out damp, and are often recommended in specifications for facing.

At Shepton Mallet remains of a Roman Potter's kiln were discovered in 1864,† and the material that had been used was probably the Lower Lias clay, which is used for brick-making in the neighbourhood.

The Lower Lias clay is used in potteries at Cranham near Painswick (see p. 143), and at Loseby, E.N.E. of Leicester (see p. 170), and the Upper Lias clay was used at Fawler. Only the coarser kinds of earthenware are manufactured.

Most of the Lower Lias clays are stiff and calcareo-argillaceous or shaly; there are seldom any loamy beds, such as are naturally adapted for brick-making. Milder or loamy earths are to be found in the lower part of the Middle Lias, and such beds are worked south of Allington near Bridport, near Ilminster and Glastonbury, at Stroud, Banbury and other places.

In the Upper Lias the clays are usually stiff, but in Dorsetshire and Somersetshire they are loamy in character. These milder beds are worked for brick-making near Bridport and at Yeovil.

The Upper Lias clays are most extensively worked for making bricks, tiles, and drain-pipes, from the neighbourhood of Banbury, through Northamptonshire to Lincolnshire.

Near Northampton, "Cimolia" of a dark lead colour was formerly used for making tobacco-pipes.‡ At the present brickyards near Kingsthorpe, red bricks and tiles are manufactured, includ-

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* Notes on Building Construction, Part III. (Rivingtons), p. 86.

† Rev. H. M. Scarth, Proc. Somerset Arch. and Nat. Hist. Soc., vol. xiii. p. 1.

‡ J. Woodward, Nat. Hist. Foss. England, Part I., 1729, p. 4. Cimolia is a term that has been applied to fuller's earth.

ing moulded, pressed and common bricks, pantiles, ridge-tiles, copings, flooring-, and oven-squares.

In other places as at Seaton, building-, well-, and floor-bricks, roof-, ridge-, floor-, and drain-tiles, garden- and chimney-pots are manufactured.

### *Sands.*

The sandy beds of the Lias, with the exception of those belonging to the passage-beds (Midford Sands), are seldom employed for economic purposes. The Midford Sands will be referred to in the volume dealing with the Inferior Oolite.

In the upper part of the Middle Lias in certain areas there are sands with hard concretionary masses of calcareous sandstone. These beds are well shown on the Dorsetshire coast, but as a rule the sands are more or less loamy and calcareous, and are not adapted for any particular economic purposes.

A micaceous sandy loam obtained at Thrupp (Thorpe), about 2 miles N.E. of Daventry, was used for moulds by the Bell-Founders.* This no doubt was Middle Lias.

### *Phosphates.*

No phosphatic deposits of economic value are known to occur in the Liassic rocks of this country.

True Coprolites are found occasionally in the Lower Lias. The name was given by Buckland,† in 1829, to nodules that represent the fossil fæces of Saurians and Fishes, many of which were obtained at Lyme Regis.

Phosphatic nodules and phosphatized fossils occur in the Lower Lias near Radstock. A sample analyzed by W. W Stoddart, showed the following composition‡ :—

| | |
|---|---|
| Calcic carbonate | 23·11 |
| ,, sulphate | 1·49 |
| ,, phosphate | 47·12 |
| Iron peroxide | 0·88 |
| Alumina | 12·16 |
| Silica | 7·10 |
| Moisture | 8·14 |
| Bituminous matter | trace. |
| | 100·00 |

Although the percentage of phosphate of lime is considerable, there are injurious ingredients in the silica, alumina, and carbonate

* J. Woodward, Nat. Hist. Foss. Eng., Part I., p. 9.

† Proc. Geol. Soc., vol. i. pp. 97, 143; Trans. Geol. Soc., ser. 2, vol. iii. p. 223. These Coprolites were originally named "Bezoar-stones," from their external resemblance to the concretions in the gall-bladder of the Bezoar-goat, once so celebrated in medicine. (See p. 70.)

‡ E. B. Tawney, Proc. Bristol Nat. Soc., ser. 2, vol. i. p. 181.

of lime. Moreover the deposit is not sufficiently rich in phosphatic nodules to be of commercial value.

Small phosphatic nodules have been noticed in the higher beds of the Lower Lias near Banbury, in the lower part of the Middle Lias in Lincolnshire, and in the Marlstone of Leicestershire.

*Lignite and Bituminous Shales.*

No beds of lignite of any economic importance occur in the Lias of the area under consideration.

Small lenticular masses, sometimes presenting the characters of jet, have been found in the Lower Lias clays of Dorsetshire, Gloucestershire, Leicestershire, and Shropshire: impure lignite occurs occasionally at all horizons in the Lias. Prof. Judd notes the occurrence of jet in the Upper Lias, and mentions that at Alexton, masses of it, after being soaked in oil to prevent cracking, are used by the workmen for whetting razors. Lignite has also been found, in digging a well, at Thorpe Mandeville.

Its occurrence in the dark and sometimes bituminous shales of the Lias has led to fruitless trials for coal. (See p. 150.)

Thus in the Lower Lias, borings have been made near Axminster,* near Chard,† (400 feet); near Badgworth; at Glastonbury (shaft sunk near George Inn, in 1792); at Bretforton‡ (shaft sunk 300 feet, about the year 1831); near Thrussington, N.E. of Leicester, at a place called Coal-pit Lees; at Huckerby (?), between Pilham and Willoughton, E.N.E. of Gainsborough;§ in several places between Whitchurch and Market Drayton (see p. 180); and near Carlisle (p. 183). In the Middle and Lower Lias a boring was made about the year 1833, near Billesdon Coplow, east of Leicester; it was carried to a depth of 600 feet.|| A boring was also made at Batheaston (p. 135). Borings have also been commenced in the Upper Lias at Neville Holt (100 feet), and near Stamford (500 feet).¶

Other borings that penetrated the Lower Oolites, will be mentioned in the volume dealing with those formations.

It has been stated that the paper-shales in the Upper Lias at Alderton Hill in Gloucestershire, are more or less bitminous, and "capable of distillation"; no analysis, however, has been made. Dr. Smithe informs me that the Upper Lias shales at Churchdown Hill are also bituminous, but the amount of material locally present would be too small to be of economic value.**

*Iron-ores.*

The Jurassic rocks furnish the greater part of the iron-ore raised in this country, and of this the Lias yields a considerable portion.

The occurrence of ore of economic value is local, and its concentration is evidently subsequent to the accumulation of the strata.

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* Conybeare and Phillips, Geol. Eng. and Wales, p. 264.

† De la Beche, Report on Geol. Cornwall, &c., p. 515. See also p. 74 of this Memoir.

‡ Memoirs of H. E. Strickland, p. 83.

§ Conybeare and Phillips, Geol. Eng. and Wales, p. 265. The spot referred to above as Huckerby, is given as "Thickerby seven miles east of Gainsborough."

|| Conybeare, Phil. Mag., ser. 3, vol. iii. p. 112; Judd, Geol. Rutland, p. 62.

¶ Judd, *Ibid.*, pp. 104, 107.

** F. Smithe and W. C. Lucy, Proc. Cotteswold Club, vol. x. p. 204 and plate; Smithe, *Ibid.*, vol. iii. p. 45. See also B. Thompson, Journ. Northampton Nat. Hist. Soc., vol. iii. p. 185.

In the area under consideration we find workable ores in the Lower Lias of Lincolnshire, and in the Middle Lias of Oxfordshire, Northamptonshire, Leicestershire and Lincolnshire.

The ores are usually obtained by open works at spots where the beds come to the surface, but in some cases the beds are worked in tunnels beneath a covering of other strata. In most cases the ore obtained is that known as Brown Hæmatite (hydrated peroxide of iron), and it consists mainly of those portions of the rock that have become weathered along the outcrop. The lowest beds exposed, and those otherwise procured from a depth, are usually grey or bluish grey, and they exhibit kernels of grey or green ironstone.

In the grey unweathered rock, the ore is mostly in the form of carbonate of iron, while the green portions are probably coloured by silicate of iron, for, as Mr. A. B. Dick informs me, there is not a sufficient amount of phosphoric acid to produce any effect on the tint. Speaking of the Cleveland ore, Mr. Dick says "The green colour of the ore seems to be due to a silicate containing peroxide and protoxide of iron, but this could not be exactly determined because it was not found possible to dissolve out the carbonates without acting at the same time upon the silicate of iron."*

The peroxidation of the ores, as pointed out by Mr. J. D. Kendall, has caused a general diminution in the volume of the strata, to the extent of about 12 per cent. This furnishes an explanation of the open joints and the increased porosity of the ore at the outcrop, at the same time the iron is as it were more concentrated.† Hence the weathered beds furnish the richer ironstone.

The quality of the different layers of ironstone is exceedingly variable in all localities, some of the beds being much more calcareous than others, and the proportion of carbonate of lime is as a rule greater in the strata, and they are much harder, the further they are followed from the outcrop. Thus where the beds outcrop along a steep escarpment the ore is not so rich, and the expense of working it would be greater, than in those areas where the beds occur over a wide belt at the surface.

Particulars concerning the strata having been previously given, it will be necessary only to add a few notes on the characters and qualities of the beds of ironstone: further remarks on the structure and origin of the beds are deferred for publication in the volume dealing with Oolitic ironstones.

The iron-ore of Frodingham, in Lincolnshire, was recognized in 1859, and soon afterwards it was worked.

The bed occurs in the Lower Lias (zone of *Ammonites semicostatus*). Its maximum thickness is stated to be 30 feet, and owing to its slight dip (towards the east), combined with the level nature of the ground, its outcrop occupies a wide stretch of country. The average workable thickness of iron-ore is about

* Iron Ores of Great Britain, Part I. p. 96.

† Trans. N. of Eng. Inst. of Mining Engineers, vol. xxxv. p. 147: see also Iron Ores of Great Britain and Ireland, 1898.

12 feet, for the quality of the beds is very variable, the bottom-layers of a grey or greenish colour being comparatively poor.

About 2,000 tons of ironstone were raised in 1859, and the amount increased in 1874 to 360,352 tons; of late years the published statistics are merged with those of other Lincolnshire iron-works. (See Table, p. 306.)*

The richer ore contains nearly 40 per cent. of metallic iron, and the poorer shelly bands about 12 per cent. The first furnace at Frodingham was erected in 1864.†

The following notes on the Frodingham ironstone were written by Mr. J. J. H. Teall, who examined the rock microscopically and chemically:—

"The ironstone consists of oolitic grains of ferric oxide showing concentric structure; and of grains, which appear to be pseudomorphs in ferric oxide, of rolled organic fragments. These occur in a matrix of calcite.

"The replacement by iron-compounds (? carbonate) appears to have taken place before cementation. If not, why was not the matrix also affected as it was in the case of the Cleveland ore?

"The residue comprises siliceous balls, quartz, and flakes of white mica."

In reference to these notes, it may be interesting to quote the remarks of Mr. Allan B. Dick, on the Cleveland Ore. He says "Throughout the ore are diffused irregularly a multitude of small oolitic concretions, together with pieces of an earthy substance resembling the ore but lighter in colour. When a mass of this ore is digested in hydrochloric acid till all carbonates and soluble silicates are dissolved, there remains a residue having the form of the original mass of ore. It is extremeiy light, and falls to powder unless very carefully handled. It contains the oolitic concretions, or else skeletons of them, which dissolve completely in dilute caustic potash, showing them to be silica in a soluble state. Under the microscope some of them are seen to have a central nucleus of dark colour and irregular shape, but none of them present any indication of organic structure or radiated crystallization."‡

Ironstone-nodules occur in the top beds of the Lower Lias, and in the lower beds of the Middle Lias, more especially in Gloucestershire.

The Rev. P. B. Brodie mentions that ironstone was formerly worked at Robin's Wood Hill, near Gloucester.§ It seems that the forging of iron was once carried on here to a considerable extent. The ore was dug out of the hill, and the works were probably continued as long as a sufficient supply of wood could be found in the neighbourhood.||

* J. D. Kendall, Trans. N. of Eng. Inst. of Mining Engineers, vol. xxxv. p. 22.
† Ussher, Geol. N. Lincolnshire, p. 22.
‡ Iron Ores of Great Britain, Part I., p. 95.
§ Quart. Journ. Geol. Soc., vol. ix. p. 31.
|| G. A. Williams, New Guide to Cheltenham, p. 187.

Layers and globular concretions of ironstone were found by Mr. G. E. Gavey about the junction of the Lower and Middle Lias at Mickleton Tunnel, near Chipping Campden; and similar beds have been noticed to the north of Dumbleton Hill, and at Hewlets Hill, Charlton Kings and Leckhampton, near Cheltenham.

These layers cannot be considered to be of economic value. They occur at the base of the partially pervious loamy clays of the Middle Lias, and may be due to the waters that have percolated from the upper ferruginous beds of the Middle Lias.

It is at the summit of the Middle Lias, in the Marlstone or Rock Bed, that we find the most valuable beds of iron-ore in certain localities, near Woodstock and Banbury, and between Market Harborough and Lincoln.

Nowhere in Dorsetshire and Somersetshire does the Middle Lias yield any important layers of ironstone, though here and there a thin layer may be found to yield a good per-centage of iron-ore, and the stone as a rule is an iron-shot earthy limestone.

Thus at Ilminster, the Marlstone was found on analysis to yield the following ingredients :—

| | |
|---|---|
| Carbonate of iron - - - | 36·53 |
| Carbonate of lime (with traces of carbonates of magnesia, manganese, &c.) - | 30·14 |
| Sand and clay - - - - | 33·33 |
| | 100·00 |

The total quantity of iron present here amounts to 15 or 16 per cent.

Another thin band of ironstone (1ft. 8ins.) was noticed by Charles Moore in the Middle Lias at Upton Cheney near Bath. In this case analysis showed an average of 24 per cent. of metallic iron in the rock.

Beneath the Marlstone near Stinchcombe, there are ferruginous beds. There, shafts have been sunk, but without a profitable result, the average yield of metallic iron being about 17 per cent.*

Where the Marlstone furnishes a valuable ironstone it is often interbedded with fossiliferous layers ("jacks") crowded with *Rhynchonella tetrahedra* and with *Terebratula punctata.* In many cases the fossils are filled with calc-spar, but in other cases the shell has been dissolved away and only casts in ironstone remain.

At Fawler, Adderbury, and (recently) at Hook Norton in Oxfordshire, and at King's Sutton in Northamptonshire, iron-ores have been obtained from the Middle Lias.

The iron-stone at Fawler near Stonesfield was discovered in 1859. It is usually spoken of as the Blenheim iron-ore, being situated not far distant from Blenheim Park, Woodstock.

Prof. Hull remarks that "The appearance of the rock at the surface indicates its strongly ferruginous nature, but at some depth, where it has been protected from atmospheric influences, the ore is found to be of a deep green colour, and under the

* Moore, Proc. Somerset Arch. and Nat. Hist. Soc., vol. xiii. pp. 129, 147, 152.

lens beautifully oolitic."* The working of the ironstone was discontinued in 1887.

Attempts were made as early as 1859 to introduce the Marlstone of Adderbury and Kings Sutton as as iron-ore, but not till about ten years later did the attempts meet with success, when extensive excavations were made. Since then the iron-ore has been worked intermittently.

Prof. Phillips remarked that, where most productive, the beds at Adderbury yield about 30,000 tons to the acre. The poorer stone which contains much carbonate of lime, was found useful in the furnaces as limestone.†

Analysis of the samples of the better stone from Adderbury, gives from 18 to 24 per cent. of iron. The Kings Sutton stone is richer in iron, different samples according to Mr. Beesley, giving 18·7, 25·5, and 34 per cent. of iron; but the richer ores are sandy. About 1,000 tons were weekly sent from these two places.‡

The ore has been obtained by open working, and since 1882, also by mining. It is a hydrated peroxide of iron, partly yellow and partly brown, the former being "oolitic" while the brown is not. Mr. J. D. Kendall states: "There is almost a complete absence of grey or greenish cores in the upper 8 feet of the bed, but they are abundant in the lower part, and some of them are very large, for which reason this part of the bed is not worked."§

The quantity obtained at Fawler from 1859 to 1866, varied from 1,552 tons (in 1866) to 5,600 tons (in 1861). That obtained from Adderbury in 1859 was 3,410 tons, and in 1860 1,250 tons; from 1869 to 1881 the quantity varied from 1,233 tons (in 1879) to 56,536 tons (in 1872).

Ironstone has been opened up at Steeple Aston, north-east of Woodstock; and Mr. Howell has remarked that in the neighbourhood of Swalcliffe the Marlstone has been found to be a good ironstone from 6 to 9 feet thick, and that it may possibly be found worth working when the country to the west of Banbury is more opened up by railway.‖ This anticipation has been realized, for recently the Marlstone has been worked for iron-ore at Hook Norton, to the east of the railway-station.

North-east of Kings Sutton there appears to be no workable ironstone in Northamptonshire; the average thickness of the Marlstone Rock-bed is about 6 feet, and the rock is only serviceable for local building-purposes or road-metal.

A large amount of iron-ore has during the past 25 years been obtained from the Middle Lias of Leicestershire and Lincolnshire. The ore both in Leicester and in Rutland was worked in ancient times, for old slags have been met with here and there.

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* Geol. Woodstock, p. 11.

† Geol. Oxford, &c., p. 496. See also T. Beesley, Proc. Warwickshire Field Club, 1872, pp. 17–19; Proc. Geol. Assoc., vol. iii. p. 198.

‡ Beesley, *op. cit.* p. 19.

§ Kendall, Trans. N. Eng. Inst. Mining Engineers, vol. xxxv. pp. 123, 124.

‖ Green, Geol. Banbury, p. 6.

## Table showing the composition of Liassic Iron-Ores.

| Constituents. | Fawler. | Adderbury. | Eastwell. | Woolsthorpe. | Holwell. | Eaton. | Caythorpe. | Frodingham (rich ore). | Frodingham (poor ore). | Frodingham (greenish kernel). |
|---|---|---|---|---|---|---|---|---|---|---|
| Iron peroxide | 44·67 | 30·20 | 55·00 | 57·86 | 50·57 | 45·21 | 47·43 | 42·24 | 18·85 | 12·87 |
| Iron protoxide | 0·86 | 3·40 | — | — | ·57 | — | — | 4·16 | — | 14·83 |
| Alumina | 7·85 | 9·10 | 14·98 | 12·80 | 9·94 | 8·76 | 10·01 | 4·88 | 3·75 | 4·89 |
| Manganese protoxide | 0·44 | — | ·16 | ·15 | | 0·46 | | 1·37 | 3·50 | |
| Lime | 9·29 | 14·80 | 1·20 | 3·47 | 3·96 | 10·56 | 7·84 | 15·75 | 35·39 | 20·78 |
| Magnesia | 0·66 | ·70 | ·88 | | 1·17 | 1·04 | ·58 | 1·57 | 0·90 | 2·26 |
| Insoluble siliceous matter, &c. | 13·11 | 12·20 | 13·32 | 11·80 | 12·54 | 14·20 | 12·26 | 5·28 | 2·80 | 8·67 |
| Soluble silica | 0·48 | — | — | — | — | — | — | — | — | — |
| Phosphoric acid | 0·55 | ·70 | ·91 | ·90 | 1·92 | ·98 | ·40 | 0·46 | 0·27 | 1·00 |
| Sulphuric acid | — | — | — | — | Trace | — | Trace. | 0·02 | — | Trace. |
| Iron bisulphide | — | — | — | — | — | — | — | — | — | 0·26 |
| Carbonic acid | 6·11 | 13·30 | 1·90 | — | 1·86 | 18·80 | 6·96 | 22·76 | 34·82 | 23·82 |
| Water | 16·31 | 15·60 | — | — | 5·36 | | 4·33 | | | 5·31 |
| Combined water and organic matter | — | — | 11·55 | 12·78 | 11·21 | | 10·03 | — | — | 5·31 |
| Sulphur | Trace. | — | ·09 | ·04 | — | ·03 | — | — | 0·05 | — |
| | 100·33 | 100·00 | 99·99 | 99·80 | 99·13 | 100·04 | 99·84 | 98·49 | 100·33 | 100·00 |
| Metallic iron | 31·94 | 23·7 | 38·50 | 40·50 | 35·80 | 31·65 | 33·20 | 32·93 | 13·20 | 20·68 |
| Do. when calcined | 41·00 | — | — | — | — | — | — | — | — | — |
| Do. average | — | — | 30·00 | — | 30·00 | — | — | — | — | — |

*Fawler.*—Analysis by Dr. J. Percy, of average sample. Hull, Geol. Woodstock, p. 12; see also J. D. Kendall, Trans. N. of Eng. Inst. Mining Engineers, vol. xxxv. pp. 123, 124.

*Adderbury.*—E. Wilson, The Lias Marlstone of Leicestershire, (Midland Naturalist, vol. viii. reprint), p. 18.

*Eastwell.*—Analysis given by E. Wilson, *op. cit.*

*Woolsthorpe.*—Analysis by G. F. Downar; Jukes-Browne, Geol. S.W. Lincolnshire, p. 120.

*Holwell.*—Analysis given by J. D. Kendall, *op. cit.* p. 122; see also Jukes-Browne, Geol. S.W., Lincolnshire, p. 120; and Wilson, *op. cit.*

*Eaton.*—Analysis furnished by T. Daglish; Jukes-Browne, Geol. S.W. Lincolnshire, p. 120.

*Caythorpe.*—Analysis given by J. D. Kendall, *op. cit.* p. 120; see also Jukes-Browne, Geol. S.W. Lincolnshire, p. 120.

*Frodingham.*—Analysis given by Messrs. Daglish and Howse, Trans. N. of Eng. Inst. Mining Engineers, vol. xxiv. p. 23; Ussher, Geol. N. Lincolnshire, p. 22; Kendall, *op. cit.* pp. 111, 112.

In 1881 two furnaces were erected at Asfordby, near Melton Mowbray; but much of the iron-ore obtained in the district is sent away to be smelted.

Mr. E. Wilson has calculated that where the available thickness of workable ore is 6 feet, the yield would be about 12,000 tons of ore, and 4,000 tons of metallic iron per acre.*

The Middle Lias ironstone has been worked at Tilton-on-the-Hill, Holwell, Wartnaby, Long Clawson, Eastwell, Stathern, Eaton, and Harston, in Leicestershire; at Woolsthorpe and Denton, south-west of Grantham, and at Caythorpe and Leadenham, between Grantham and Lincoln. In structure the rock is more or less oolitic; but some specimens show only organic fragments that have been replaced by iron-ore.

TABLE SHOWING THE PRODUCTION OF IRON-ORE DURING THE PAST TEN YEARS.

| Districts. | | No. of Blast Furnaces. | In Blast. | Tons of Brown Hæmatite. | Average Per-centage of Iron. | Value of the Ore at the Works. |
|---|---|---|---|---|---|---|
| | | | | | | £ |
| Lincolnshire - | 1882 | 21 | 17 | 1,190,564 | 30·00 | 172,708 |
| | 1883 | 20 | 17½ | 1,006,219 | 30·00 | 135,051 |
| | 1884 | 21 | 16 | 1,260,470 | 30·00 | 150,592 |
| | 1885 | 21 | 14¼ | 1,107,003 | 30·00 | 134,793 |
| | 1886 | 21 | 13 | 1,118,534 | 30·00 | 138,642 |
| | 1887 | 21 | 13½ | 1,227,882 | 30·00 | 139,407 |
| | 1888 | 21 | 14 | 1,300,914 | 30·00 | 146,353 |
| | 1889 | 21 | 17¼ | 1,462,408 | 33·00 | 182,801 |
| | 1890 | 21 | 12¾ | 981,400 | 33·00 | 122,675 |
| | 1891 | 21 | 12¼ | 1,138,092 | 33·00 | 142,142 |
| | 1892 | 21 | 13 | 1,355,107 | 33·00 | 169,388 |
| Leicestershire - | 1882 | — | — | 267,802 | 34·50 | 33,475 |
| | 1883 | 2 | 2 | 294,825 | 34·00 | 37,100 |
| | 1884 | 2 | 2 | 261,837 | 34·00 | 32,728 |
| | 1885 | 2 | 2 | 310,529 | 34·00 | 38,815 |
| | 1886 | 3 | 2 | 390,687 | 34·00 | 48,836 |
| | 1887 | 3 | 2 | 372,773 | 34·00 | 46,592 |
| | 1888 | 3 | 3 | 535,831 | 34·00 | 60,281 |
| | 1889 | 3 | 3 | 582,858 | 34·00 | 58,286 |
| | 1890 | 3 | 3 | 609,964 | 34·00 | 60,996 |
| | 1891 | 3 | 3 | 646,125 | 34·00 | 72,689 |
| | 1892 | 4 | 3 | 680,985 | 34·00 | 70,936 |

* E. Wilson, The Lias Marlstone of Leicestershire, 8vo. Birmingham (Midland Nat., vol. viii.). See also J. D. Kendall, *op. cit.*, pp. 119, 121.

The statistics for Lincolnshire include works now, or formerly in operation, and known as the Appleby, Caythorpe, Claxby, Crosby, Frodingham, Glebe, Midland, Greetwell, Gunhouse, Normanby, Trent, Warren, and Woolsthorpe works. They include therefore, the iron-ores obtained from the Neocomian Beds, and the Northampton Sands (Dogger), as well as from the Lower and Middle Lias.

The statistics for Leicestershire include the works at Eastwell, Eaton, Harston, Holwell, Waltham, and Warnatby; and they include iron-ores from the Northampton Sands and Middle Lias.

[*See* Mineral Statistics of the United Kingdom, prepared by Her Majesty's Inspectors of Mines.]

### *Ochre.*

Ochre has from time to time been worked near East Harptree. It was obtained from the ferruginous arenaceous and cherty beds of the Lower Lias and Rhætic beds. The material was found in seams between the layers of stone, and in pockets associated with the cherty beds; and more profusely in clayey beds that underlie the main mass of stone, as well as from the Dolomitic Conglomerate. (See p. 124.) De la Beche has thus referred to the beds. "The upper or arenaceous beds have been so impregnated with silica, that a kind of arenaceous chert is the result, some of the cementing matter being so highly charged with peroxide of iron, that upon decomposition of part of the rock, excellent yellow ochre is obtained by the ordinary washing and depositing processes."*

Near the railway station at King's Sutton, there were (in 1887) works belonging to the "Anti-oxide and Colour Company," where pigments were manufactured. Material had been used from Adderbury, but the ochre from the Middle Lias proved to be too siliceous, and the ingredients were then obtained from the neighbourhood of Manchester.

### *Miscellaneous Minerals.*

Of various minerals, some occur in a detrital form in the rocks, while others are due to chemical changes in the mass of the strata, or they occur in joints and crevices of the rock from the infiltration of waters holding various substances in solution.

But little is at present known with regard to the minor mineral ingredients of the Liassic rocks. *Mica* is present in most of them. *Galena* has been found in small quantities in the Sutton Stone (Lower Lias, of Glamorganshire), where it is mostly in a detrital condition, being derived from the Carboniferous Limestone. *Blende* has also been noticed. (See pp. 98 and 102.)

*Manganese-ore* has been detected in small quantities in the Lias of Frocester and Ilminster, and in the form of *Rhodonite,* it has been recorded from the Middle Lias of Churchdown and Gretton.† Belemnites also occasionally contain traces of this ore in their composition.‡

*Specular Iron* has been noted by Prof. Judd, in nodules of ironstone from the Middle Lias. Of other iron-ores *Earthy Carbonates of iron*, *Limonite*, and occasionally red *Hæmatite* are found: but the more extensive beds of ironstone have already been mentioned.

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* Mem. Geol. Survey, vol. i. p. 277.

† F. Smithe, Proc. Cotteswold Club. vol. viii. p. 33.

‡ J. S. Miller, Trans. Geol. Soc., ser. 2, vol. ii. p. 46.

*Iron Pyrites* and *Marcasite* (Rhombic Iron Pyrites) are found more especially in the Lias shales. They are most abundant in the shales of the Lower Lias. At Black Ven, near Lyme Regis, there is a "Metal Bed," and material derived from this and other layers, was formerly collected during the winter months, for the preparation of copperas (sulphate of iron), sulphuric acid, and sulphur. Examples of Marcasite from Lyme Regis are sold to visitors as "Angel's Wings."

In the year 1755, spontaneous combustion occurred in the bituminous shales of the Lower Lias at Charmouth.* This took place among fallen masses of the strata, owing to the decomposition of pyrites. In 1890, similar combustion took place further east, and in the "Daily Graphic" of Feb. 19th, there appeared a picture of the "eruption" of Golden Cap.

*Selenite* occurs in the Lias clays, but most abundantly in the Upper Lias in Northamptonshire and Leicestershire.

*Calcite* is found plentifully on the joint-faces of the limestones, in crevices of the rocks, and lining the interiors of Mollusca aud other fossils. Nail-head spar, a peculiar form of crystalline carbonate of lime, is met with in the Upper Lias of Northamptonshire. This form presents the "cone-in-cone" structure; the surfaces of the cones being fretted with irregular crystalline coats, due perhaps to a kind of "concretionary crystallization."† Seams of fibrous carbonate of lime, known as "Beef," also occur in the Lias clays. (See p. 277.) Small concretions of the same substance, are known as "Race"; and this often has a septarian structure.

*Barytes* (*Heavy Spar*) occurs in the Cherty Lias of Harptree; and it has been recorded from the Lower Lias near Gloucester.‡ (See p. 98.)

*Quartz* crystals and *Chalcedony* occur in the Lower Lias of Glamorganshire, and in the Cherty Lias of Harptree.

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* Buckland and De la Beche, Trans. Geol. Soc., ser. 2, vol. iv. p. 23.

† See also G. A. J. Cole, Mineralogical Mag., vol. x. p. 136.

‡ Conybeare and Phillips, Geol. England and Wales, p. 265.

# CHAPTER XII.

## ECONOMIC GEOLOGY—(*continued*).

### Agriculture, Springs, and Water Supply.

#### *Physical Features.*

The physical features being dependent on the nature and inclination of the rocks, we find the more prominent ridges or escarpments formed by the Lower Lias Limestones and by the Marlstone.

The Lias in Dorsetshire is more or less masked by coverings of Cretaceous rocks, but further north the Lower Lias forms a marked escarpment near Curry Rivell on the borders of the Vale of Taunton, and again in the Polden Hills. These are perhaps the most conspicuous features in the entire area, formed by the Lower Lias; minor escarpments are formed in North Gloucestershire, Worcestershire, and Warwickshire. The more elevated tracts found in other places, as on the Leicestershire Wolds, are largely formed of Glacial Drift.

The Marlstone and underlying sandy beds, form a marked escarpment between Ilminster and Yeovil, but onwards along the main Oolite escarpment, the Middle Lias is nowhere very prominent, except near Dursley and Stinchcombe, where it forms a platform beneath the main escarpment of the Cotteswold Hills.

It reaches its highest elevation in the fine scarp of Edge Hill (710 feet), and in Northamptonshire and Leicestershire it stands out more or less prominently, rising to a height of 755 feet at Tilton-on-the-Hill, and forming a conspicuous hill in the Vale of Belvoir, crowned by Belvoir Castle.

The main mass of Lias Clays, comprising the higher portions of the Lower Lias and the lower portions of the Middle Lias, forms a succession of vales. These include the vales of Marshwood, in Dorsetshire; of Ilchester and Sedgemoor (in part), in Somersetshire; of Glamorgan; of Berkeley, Gloucester, Cheltenham, Winchcomb, and Moreton, in Gloucestershire; of Evesham, in Worcestershire and Gloucestershire; of Shipston and of the "Red Horse," in Warwickshire; and of Catmos, Mowbray, and Belvoir, in Rutlandshire, Leicestershire, and Nottinghamshire.

Further remarks on the character of the scenery and the causes influencing it, are reserved for a subsequent volume dealing with the Oolitic rocks.

#### *Drift Deposits.*

In the south-western counties the Liassic rocks are comparatively free from Drift, and it is not until we pass to the north and

north-east of Oxford, beyond Chipping Campden and Banbury, that the strata are much obscured. Thence through the counties of Warwick, Northampton, Rutland, Leicester, and Lincoln, the beds are largely concealed beneath coverings of Boulder Clay, Sand, and Gravel.

The superficial accumulations that overlie the Lias in the south-western counties, are confined mainly to valley-gravels, such as border the river Char in Dorsetshire and the Axe in Devonshire. Scattered gravels occur also in the Vale of Ilchester, in the Brue valley near Castle Cary, along the Avon valley near Bath and Keynsham, and the Severn valley near Stroud and Gloucester. Further north there occur not only valley-gravels bordering the rivers, but, as before mentioned, extensive beds of Glacial Drift.

Beds of rolled oolite-gravel, and coarser accumulations with large blocks of Jurassic rocks and Cretaceous materials, occur here and there in the Vale of Moreton, near Bourton-on-the-Water, Aston Magna, and Mickleton. In this neighbourhood we have remnants of valley-gravel and the most southerly traces of Glacial Drift, some of the accumulations noted having a thickness of 70 feet or more.* The beds, however, have not at present been mapped in detail.

Strickland pointed out that the Vale of Shipston (Shipston-on-Stour) probably marked the western limit of the "Flinty Drift" (by which term he included the Boulder Clay or Northern Drift).† In the Vale of Evesham and bordering tracts we find the Lower Lias curiously disturbed in places at the surface, the limestones and clays being nipped up in a series of sharp folds. Such features were exhibited at Croome D'Abitot and South Littleton. (See Fig. 51, p. 146.)

At Honeybourne the Lower Lias clay is contorted in places, and this we find to be the case here and there as we trace the Liassic beds onwards to Lincolnshire. Near Blisworth in Northamptonshire the Upper Lias clay is remarkably contorted beneath the Boulder Clay. (See Fig. 89, p. 277.)

Near Rugby the superficial deposits include extensive beds of sand and gravel, 70 to 90 feet thick in places, with also Boulder Clay. Over large tracts there is a thin covering of sandy and loamy soil with quartzite pebbles; while near Church Lawford and at other localities there are Pleistocene valley gravels.‡

In Leicestershire there are beds of Drift sand and gravel, and Boulder Clay, that attain in places a thickness of 200 feet.§ Further north, in Lincolnshire there are various Drift deposits, and these have been described in the several Geological Survey Memoirs on that area.

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* G. E. Gavey, Quart. Journ. Geol. Soc., vol. ix. p. 29; W. C. Lucy, Proc. Cotteswold Club, vol. v. p. 71, and vol. vii. p. 50.

† Memoirs of H. E. Strickland, p. 90.

‡ Explanation of Horizontal Section, sheet 140, p. 11.

§ Judd, Geol. Rutland, p. 141; Deeley, Quart. Journ. Geol. Soc., vol. xlii. p. 43

*Soils.*

The Liassic areas are almost entirely under cultivation: the tracts formed of the stone-beds being mostly under tillage, and those formed of clay being mostly grass-lands.

The Lower Lias limestones furnish a brown loamy and brashy soil of variable depth and porosity, on which crops of corn and roots are grown. In Glamorganshire some of the limestone-tracts afford pasturage for sheep, but much of the Lias country there yields wheat of fine quality, also beans, oats, barley, and turnips, while samphire grows luxuriantly on the borders of the grey Lias cliffs.*

The soil on the Middle Lias in the south of England is a rich brown friable loamy and clayey soil, and the districts covered by it are almost entirely agricultural. The land is marked by small enclosures, as in the Vale of Marshwood and near Bridport, where roots, corn, beans, grasses and vegetables are cultivated. The more sandy areas are marked by the occurrence of the brake-fern and by fir-trees, but in most tracts oak and ash grow well in the hedgerows, and there are many fine elms as well as beeches. Some of the hedge-rows in Dorsetshire and again in Oxfordshire are very luxuriant, while the deep sandy lanes, or "hollow ways," excavated in the soft beds, as between Colmers Hill and Leaz-acre near Bridport, and at other localities in Dorsetshire are very picturesque.

In Dorsetshire and South Somersetshire the Marlstone in many places is very thin, and it decomposes into a brown ferruginous loamy soil; but where the rock is thicker there is a good deal of rich arable land, as near Ilminster and South Petherton.

The red ferruginous soils on the ironstone-rocks of the Middle Lias of Oxfordshire, Northamptonshire, Leicestershire, Rutlandshire and Lincolnshire, are as a rule highly productive. The soil is often a deep sandy loam, which "works well," although apt to harden and crack in summer. Rutland indeed owes its name to the "red land" which extends over much of the vale of Catmos, but part of it is due to the ferruginous beds of the Northampton Sands. Corn and roots are grown. The richness of some of the red lands is attributed by Mr. B. Thompson to the presence of phosphoric acid in the Marlstone.† (See also p. 222.) The deep red loam found near Barrowby and Great Gonerby, near Grantham, is considered to furnish some of the most fertile tracts in Lincolnshire.‡

The Upper Lias furnishes a loamy soil in Dorsetshire and South Somerset§ Northwards for some distance it exercises little

* See Conybeare and Phillips, Geol. England and Wales, p. 277.

† Middle Lias of Northamptonshire, p. 71.

‡ J. A. Clarke, Journ. R. Agric. Soc., vol. xii., p. 259.

§ For Analyses of soils from Montacute, and Combe Farm N.W. of Sherborne, see A. Voelcker, Journ. Bath and W. of Eng. Soc., ser. 2, vol. vi. p. 262; and for Analysis of soil from South Petherton, see T. D. Acland, Journ. R. Agric. Soc., vol. xi. p. 720.

influence on the agricultural features, and along the Cotteswold Hills its presence is indicated by grassy slopes beneath the Midford Sands and Inferior Oolite, the soil being largely made up of a downwash of sands from the beds above. On the steep western slope of the Lincolnshire "Cliff," the soil over the Upper Lias clay is likewise rendered fertile by a downwash from the superincumbent strata.

In the vales formed of Lias, and in the narrow valleys of Lias clay that intersect the Oolitic escarpments, we find most of the permanent pasture- and meadow-land. These tracts are divided by well-timbered hedge-rows, and almost everywhere the characteristic oak will flourish, while the elm and ash likewise abound. The fertility of particular tracts varies according to the nature of the clay, whether marly or loamy or very tenacious, the situation and elevation of the ground, and according to whether the soil is modified by a downwash of material from the adjoining uplands, or from scattered superficial deposits of gravel and sand. Where the bare clay comes to the surface, the soil is often stiff, cold and retentive, and requires much draining and manuring before it becomes productive. Much of the Lias clay is calcareous, but as a rule it is too deficient in lime to be employed for marling the land; the Lower and Upper Lias clays are the stiffest, the more loamy clays being found in the Middle Lias at the base of the Marlstone.

The Vale of Marshwood in Dorsetshire is a tract formed partly of somewhat cold and stiff Lower Lias clay, bordered by more fertile lighter lands of Middle and Upper Lias. It includes some excellent pasture-land, and yields a good soil for orchards; hence the Dorset butter and cider are noted.

Among the products of the Liassic and Alluvial pastures of Somersetshire, south of the Mendip Hills, may be mentioned the Cheddar Cheese; and of the Vale of Berkeley the Gloucester Cheese; while the famous Stilton cheeses are most largely produced from stock fed on the pastures of the more or less Drift-covered tracts of Lias, near Melton Mowbray in Leicestershire.

The Wolds of East Leicestershire, formed of Lias clay with cappings of Drift, furnish well-known sheep-walks; and there is rich grazing-land near Market Harborough. Northwards in Lincolnshire the soil on the Lower Lias is a cold clayey loam, but its character is modified in many places by coverings of Drift.

Wheat, beans and teazels are cultivated in places; teazels more especially in the Vale of Ilchester. Hops were formerly grown in places, as at Bitton near Bath. Canon Ellacombe mentions that in many parishes there are fields called Hop Gardens, but the cultivation ceased to pay when it was cheaper to buy hops grown on more favourable soils.*

* Proc. Bath Nat. Hist. Club, vol. vi. p. 187.

The neighbourhood of Evesham is especially noted for its market-gardens and orchards, a large amount of fruit and vegetables being cultivated for the market.

The development of trade here, is due partly to the soil and to the low and sheltered situation, and partly to the facility for transport of the material by rail. The sub-soil of this tract of country is chiefly Lower Lias clay, of a more or less calcareous nature, with coverings here and there of sand and gravel; it is said to be better adapted than the New Red Marls for market-gardening, but the fertility requires to be maintained by manuring.* Much jam is made at Pershore, Evesham, and Toddington, north of Winchcomb.

The fertility of the soil at Evesham, was early recognized, for the land was partly on this account chosen by the Monks who erected the Abbey. At one time there were vineyards here, and also in the Vale of Gloucester; their former presence is indicated by Vineyard Farm, south of Charlton Kings, near Cheltenham, and in some of the field-names near Bath and Claverton. There were vineyards also at Meare and Pamborough, near Glastonbury.†

Another product of the Liassic clay-lands, is much of the Cider of Dorsetshire, Somersetshire, Gloucestershire, and Worcestershire; for the Apple-tree likes a "stiff land inclined to clay," or a calcareous clayey soil with a dry subsoil. The trees grow well in some of the old limestone-quarries near Street, in Somersetshire (see p. 294), but some of the best localities in Somersetshire are along the borders of the junction between the Lower and Middle Lias, near Martock, Tintinhull, Queen Camel, and Cadbury.‡ There are also good orchards near Tewkesbury, and along the borders of the Cotteswold Hills.

The vales of Moreton-in-the-Marsh, Evesham, Fenny Compton, Market Harborough, Melton Mowbray, and Belvoir, are among the more celebrated fox-hunting tracts.

The clay lands of the Lias furnish remnants here and there of some of the Forests of ancient fame, but they are not so noted as some of those that formerly extended over the clays of the Oolitic Series. Portions of the old Forests of North Petherton, Neroche, and Ashill, in Somerset; of Rockingham; of the Forest of Arden around Henley-in-Arden, and Hampden-in-Arden; and of Delamere in Cheshire, extended over tracts of Lias.

### *Terraces of Cultivation.*

Old terraces of cultivation, known as lynchets, or linchets, may be observed in many tracts, more especially along the Middle Lias slopes.

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* See Memoirs of H. E. Strickland, p. 80.

† Canon H. N. Ellacombe, Proc. Bath Nat. Hist. Club, vol. vi. p. 137, vol. vii. p. 35.

‡ For Analyses of soils from Street and Long Sutton, in Somerset, see Voelcker, Journ. Bath and W. of Eng. Soc., ser. 2, vol. vi. p. 263.

They may be seen near Bridport, on Brent Knoll, occasionally in the Cotteswold Hills, and some well-marked terraces have been noticed at Shenington, and Alkerton, near Banbury, and at Burton Dassett. They occur also near Tilton-on-the-hill.

In these districts the terraces are found generally on the micaceous sands and clays, below the Marlstone rock-bed.

Mr. E. A. Walford has attributed the terraced hill-slopes near Banbury to natural causes, partly to the slipping and sliding outwards of the saturated porous strata upon the tenacious clays, aided by pressure of the superincumbent Rock-bed, and partly to the removal by chemical agency of calcareous matter from the beds.* I cannot accept this explanation. In all cases that I have noticed, these features terminate abruptly, and show no resemblances to the irregular terraces and broken ground due to landslips. The explanation that they are old terraces of cultivation, is by far the most plausible one, and their occurrence on the slopes formed of the Middle Lias sandy clays, may be attributed to the fact that these tracts were found to be more fertile and more readily cultivated than the probably wooded tracts on the Lias clays.

Over large areas of the Liassic "grass country," there is evidence that much of it was originally "plough land," from the ridge and furrow due to former agricultural operations. In some parts of Leicestershire the old furrows are from one to three feet deep.

### *Distribution of Population.*

The distribution of towns and villages on the Lias, as on other formations, bears a close relation to the means of obtaining a water-supply.

In the tracts where the Lias is comparatively free from Drift, we find that the settlements were originally made near the escarpments, whether of the Lower Lias limestones or of the Marlstone. Springs issue from the base of the Lower Lias limestones and White Lias, and again more copious springs flow from the base of the Middle Lias "Marlstone," or from the underlying sandy beds.

On the broad flats of Lower and Middle Lias clay, the few villages are usually very small, excepting in places where gravel occurs.

Of the larger towns or cities placed for the most part on Lias, Bath is nearly surrounded by hills, that throw out many springs, and of course owes its development to its natural thermal waters. Gloucester is situated on gravel overlying Lower Lias; and Cheltenham occupies a somewhat similar geological position, its growth being due to the mineral waters obtained by sinking to some little depth beneath the surface.

### *Water-bearing Strata.*

On the Upper Lias clay, the villages usually draw their supplies of water from springs thrown out on top of the clay, at its

* Journ. Northamptonshire Nat. Hist. Soc., 1890.

junction with the variable beds grouped, for the sake of convenience, with the Inferior Oolite Series. Accounts of these springs will be given in the Memoir dealing with the Oolites. Some of the beds of much-jointed paper-shale in the lower part of the Upper Lias of Gloucestershire, allow water to freely pass through them.*

The Lower Lias limestones yield a variable supply of water, but although the strata attain a thickness varying from 20 to nearly 200 feet, we have no records of any very copious supply being yielded. Constant supplies of water are obtained from the Lower Lias, in a well 129 feet deep, at Somerton; and at Twerton coal-pit near Bath, a spring in the Lower Lias, at a depth of 72 feet, yielded 16,800 gallons of water per day. This water was saline.† (See p. 321.) A boring at Shepton Mallet carried to a depth of 98 feet, found no water.

Many of the springs that issue are very permanent, and in seasons of long drought, they continue to yield a supply. Such is the case on the Glamorganshire coast near Southerndown. Owing, however, to the alternation of clays with the limestones, percolation is slow, and no large bodies of water are likely to be stored up in the mass of the strata.

A well sunk at Harbury, in Warwickshire, to a depth of 37 feet in the Lower Lias limestones, yielded 90 gallons of water per hour. Higher beds in the Lower Lias occasionally yield limited supplies of water. Thus at Saxby, near Melton Mowbray, a yield of about 5,000 gallons per day was met with in limestones that occur in the clays at a depth of 225 to 240 feet. The water rose to within 4 feet of the surface.

The Marlstone and underlying sandy beds of the Middle Lias are usually water-bearing strata.

In the south of England the sands beneath the thin representative of the Marlstone are the chief holders of water, as at Glastonbury. The Marlstone, and the Basement-beds of the Upper Lias, yield supplies suitable for cottages as in the neighbourhood of Yeovil; and sometimes a good supply has been obtained, as at the Yeovil gas-works, where the water rose to the surface.

In South Gloucestershire the Marlstone is poorly represented, but it becomes more important near Wotton-under-Edge. Eastwards again it is variable in character.

At Kingham Hill, near Chipping Norton, a well sunk through 50 feet of Upper Lias to a further depth of 50 feet (with headings) in the Middle Lias, yielded about 1,000 gallons per day at the end of a very dry season.

In the midland counties from the neighbourhood of Banbury to Grantham, the Marlstone is perhaps the most important source of water. Nevertheless, in some places the Rock-bed is too thin to hold much water. A trial-boring at Castor, near Peterborough, carried to a depth of 286 feet, failed to find any large quantity of water.‡

* F. Smithe and W. C. Lucy, Proc. Cotteswold Club, vol. x. pp. 202, 204.
† De Rance, Rep. Brit. Assoc. for 1875, pp. 118, 141; *Ibid.* for 1882, p. 214.
‡ J. Addy, Proc. Inst. C.E., vol. lxxiv., p. 147.

A shaft sunk in 1836 at Kingsthorpe, near Northampton, penetrated the Middle Lias, which yielded about 864,000 gallons of water per day. No use was made of this water, for the sinking was carried (in search of coal) to a depth of 967 feet, and then encountered saline water. Mr. B. Thompson remarks (1888) that the salt water fills the old shaft to within 270 feet of the surface.

Northampton was about 10 years later (1846) supplied by a well (near the Billing Road), sunk and bored 168 feet into the Marlstone. About 500,000 gallons per day were at first obtained, and the water rose to within 60 feet of the surface. Later on a second well was sunk. In 1871 about 280,000 gallons of water were daily supplied; but the total amount available was found steadily to decrease. Some temporary increase was obtained by means of headings, but many old wells were rendered dry, as the water-level was reduced, and in 1884 the water did not rise above the Marlstone rock-bed. As pointed out by Mr. B. Thompson, more water (from this and other wells in the neighbourhood) was pumped from the Marlstone than it received from natural sources. He proposed a scheme to supply the deficiency by means of dumb-wells constructed to take surplus waters from the Nen and tributaries. This scheme was not adopted.*

A reservoir intended to hold 400 millions of gallons of water has now been constructed on the Upper Lias Clay in the valley between Ravensthorpe and Guilsborough. The brooks in this valley form one of the tributaries of the Nen, and they derive their waters from the Northampton Sands.

The dam is near to and nearly parallel with the road from Ravensthorpe to Teeton, so that the reservoir is sometimes spoken of as the Teeton reservoir, and sometimes as the Ravensthorpe reservoir. The Upper Lias clay was used in the construction of the dam.

Mr. Beeby Thompson, to whom I am indebted for the above particulars, informs me (1891) that the reservoir has probably never received half the amount of water which it was constructed to hold.

At the Midland railway-station at Wellingborough, a boring was carried through the Upper Lias to a depth of 150 feet, when the Rock-bed (Marlstone) was struck, and plenty of water was obtained.† Good water (used for brewing) was obtained from the Middle Lias (at a depth of 80 feet), one mile west of Oakham).‡ (See p. 238.)

The water obtained from the Lower Lias limestones is as a rule much harder than that obtained from the Marlstone, and it is sometimes contaminated with sulphuretted hydrogen. This is also the case with wells that are sunk through the Middle Lias into the clays at its base. In waters not subject to artificial pollution, the hardness, as might be expected, is usually less in the spring water than in the water obtained from wells, and it increases according to the depth of the well. The hardness is mostly of a "temporary" character, and can be removed by Clark's process.

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* B. Thompson, Middle Lias of Northamptonshire, pp. 78, 82, 84, 100, &c.; and B. Latham, Trans. Soc. Eng., 1864, p. 244.

† From notes made by H. W. Bristow.

‡ De Rance, Rep. Brit. Assoc. for 1879, p. 161.

The waters obtained from the Middle Lias are especially liable to variation in quality as well as quantity, as the rock-beds which constitute the chief water-bearing strata possess very different characters in different places, passing from an earthy iron-shot limestone to a rich ironstone. These waters in many places are more or less chalybeate.

The average temporary hardness of the Lias waters is stated to be about 20°; but in the "Report on the Domestic Water Supply of Great Britain," waters obtained from strata overlying the Upper Lias clay are included with the Lias waters.*

Waters obtained by shallow wells in the Lias limestones are liable to contamination from artificial sources.

With regard to the water-supply as affecting health, it has been ascertained by Mr. E. E. Berry that goitre occurs in villages (supplied with more or less ferruginous water), on the Middle Lias tracts from the neighbourhood of Banbury through Gloucestershire and Somersetshire to near Sherborne in Dorsetshire.

### *Reservoirs.*

Reservoirs to supply water for household purposes and to feed canals, have been constructed, on the *Lower Lias* near Chard, at Barrow Gurney, at the foot of Robin's Wood Hill near Gloucester, at Witcomb, at Child's Wickham, Hewlets near Cheltenham, Chattercutt near Cropredy, Bodington, Wormleighton, Napton, north of Daventry (two), near Welford, and Denton; on the *Middle Lias* at Chilcombe Bottom, Swainswick (partly Upper Lias?), Dowdeswell near Cheltenham (Lower and Middle Lias), W. of Naseby, and Knipton; and on the *Upper Lias* at Monk's Wood, S. of Cold Ashton (partly Middle Lias?), and at Ravensthorpe. Small ornamental lakes have been made in many parks on each division of the Lias.

### *Springs.*

While the general flow of the rain that falls on the Liassic and Oolitic hills is towards the south-east, along the dip-slope of the strata, yet notwithstanding this inclination, many springs issue along the escarpments at the base of the porous rocks.

Such springs originally issued when the strata became surcharged with water, and the outflow of water over the clays would tend to form in them channels, which in course of time would be deepened. Eventually the more important of these springs, draining large areas, would become of a permanent character, so that a system of underground water-courses exists.

The porous strata being natural reservoirs for the rainfall, overflow springs are found to issue not merely from the base of the strata, but where the beds are at all tilted, and succeeded by impermeable strata, springs may issue from the upper part of the porous beds, and flow along in the direction of the dip-slope, over the succeeding clayey formation.

Streams flowing across the outcrop of porous beds are known in places to lose much in bulk from percolation; but such instances

* Sixth Report of Rivers Pollution Commission, 1874, pp. 23, 79, 95, 117, 126.

are more usual among the Oolitic strata. Mr. C. Reid observed that east of Sarte (north of Axminster), where there are two streams, the main one entirely disappears, apparently into a fissure of the White Lias. About a mile and a half further north the other stream disappears in the same way.

On the borders of the Mendip Hills north of Doulting, near Shepton Mallet, the waters that flow from the Old Red Sandstone of Beacon Hill, pass in places underground through swallet-holes in the Lias. The Lias there extends across the denuded outcrop of the Lower Limestone Shales, and is banked up against the Old Red Sandstone at its junction with the Shales. Hence much water is conveyed underground through the Lias limestones, which there contain little or no shale, and it passes downwards into the Carboniferous Limestone. In the same district, along the Oolitic escarpment near Doulting, streams thrown out by the Lias Clay at the base of the Inferior Oolite, pass down in swallet-holes into the Lias limestones.

Observations with respect to the drought of 1884, recorded by Mr. G. J. Symons, show that at White Lackington, near Ilminster, "two perennial springs failed"; at Banbury, the shallow wells and surface springs were dry; at Belvoir Castle, there was a "remarkable disappearance of subsoil water," and at Doddington, near Lincoln, the springs were "very low."*

Over considerable tracts of Lias clay, well-water is not obtainable owing to the depth to which it would be necessary to bore, and other circumstances, such as the presence of saline waters. Thus at Rugby, Gayton (near Blisworth), Kettering, and Northampton, saline waters were met with after the Lias was penetrated.

In such cases springs from neighbouring hills are utilized, and the surface-waters from certain areas of gathering ground are stored in reservoirs. This is the case at Gloucester, where springs thrown out by the Lias and Oolites on the flanks of Robin's Wood Hill, and the surface drainage of 1,500 acres, are collected in a reservoir holding 62 million gallons.†

A well sunk at Gloucester penetrated the Lower Lias clays with bands of limestone to a depth of 350 feet and failed to find water.‡ It is probable that limited supplies of water would have been obtained from beds at a further depth of about 50 feet; but the limestones at the base of the Lower Lias are far less prominently developed in this part of the country than they are in many other places. Again at Chipping Norton a boring was carried to a depth of 500 feet in the Lower Lias clay and abandoned.§

* De Rance, Rep. Brit. Assoc. for 1885, p. 392.

† Sixth Report Rivers Pollution Commission, p. 348; De Rance, Report on the Circulation of Underground Waters, Brit. Assoc. for 1878, p. 404.

‡ W. C. Lucy, Proc. Cotteswold Club, vol. viii. p. 213.

§ Rev. J. Clutterbuck, Journ. R. Agric. Soc., ser. 2, vol. i. p. 282; and Geologist, vol. v. p. 128. See also T. W. Rammell, Report to the General Board of Health on Banbury, 1850.

Banbury has been supplied with water from the river Cherwell at Grimsbury, about a mile above the town. The water contains 25 grains per gallon of "solid impurity";* the total mineral salts, according to Mr. T. Beesley, being nearly 20 grains per gallon. In very dry seasons (as I am informed by Mr. E. A. Walford) there is hardly sufficient water to maintain the stream below the intake of the water-company. The town was formerly supplied by wells sunk, through the Marlstone, &c., to depths of from 10 to 150 feet.

In this account we have omitted reference to water obtained from the Drift sands and gravels that in places overlie the Lias. In most cases such water is liable to pollution, but if obtained from sands and gravels under Boulder Clay, the water may be good. An abundant supply of hard water was thus obtained at Fleckney in Leicestershire, at a depth of 45 feet.†

Some of the more prominent springs have, through their legendary virtues or associations, been designated Holy Wells, or named after some Saint; others have a local reputation from their constancy.

At Glastonbury Abbey there is a Holy Well, known as St. Mary's Well. (See p. 320.) There is also a spring on Edmund Hill, known as St. Edmund's or Elder Well. This has been used to supply the town of Glastonbury; but I am informed by Mr. T. C. Luff (1892), that since a shock of an earthquake, some 15 or 20 years ago, the yield has been much smaller than it formerly was.

At Southam there is a Holy Well, north-west of the town; it rises in the Lower Lias limestones, and has been utilized as a source of supply to the town.

South-east of Priors Marston, in Warwickshire, there is the Shutwell Spring that issues from the Marlstone.

Thackson's Well, south-west of Foston, in Lincolnshire, is a perennial spring that issues from the Lower Lias, near a line of fault.

The underground waters in the Jurassic rocks all contain some mineral ingredients, and the surface-waters, the streams and rivers consequently convey similar materials in a much more diluted form.

Springs which come to the surface through argillaceous strata, must be of an artesian character, and must find egress through cracks in these otherwise impervious beds.

In dry seasons it is noticeable how deep the surface-cracks are, while at a considerable distance down, most clays are in an indurated condition, as shown by cores from borings. Hence water from a considerable depth may rise through joints or faults in argillaceous strata. In this way only can we account for the rising of waters, as at Bath, Cheltenham, or Shearsby, through the Lias clays, or at Purton through the Oxford Clay.

During the dry season of 1885, I noticed huge cracks in the fields and also in the roads, on the Oxford Clay near Witham Friary in Somerset; and in some sections of the Lower Lias and other formations, where clays with bands of limestone occur, it

* Report of Rivers Pollution Commission, p. 50.

† De Rance, Report, Brit. Assoc. for 1880, p. 106.

may be noticed that the limestone is waterworn at some depth from the surface. I observed instances near Penarth. (See also p. 271.)

The origin of the mineral matter in what may be called the Surface Springs, is readily understood, for, with the exception of atmospheric impurities, they derive their ingredients from the calcareous and ferruginous rocks through which they have percolated. These rocks and the original or secondary mineral matter they may contain, will usually account for the nature of the water. In some cases the dissolution of organic remains may have contributed saline and other materials. The origin of the saline waters will be discussed more particularly in the volume dealing with the Oolites, but it should be borne in mind that artificial manures affect some surface-waters, and that Epsom Salts may be introduced into certain Spas by other than natural agencies.

### *Petrifying Springs.*

Springs of a "petrifying" nature, depositing carbonate of lime on objects placed within their influence, or forming accumulations of tufa, have been met with in a number of places along the outcrop of the Lias limestones.

Such springs have been observed at Ford Farm, between Chilton and Stawell in Somerset (at the junction of Lower Lias and Rhætic Beds); near Dursell, Shepton Mallet; near Newton Mill, Newton St. Loe, Bath; near Warkworth, 1½ miles east of Banbury (Marlstone); at Morton Morrell, north-west of Kineton (Lower Lias limestones); at Halstead, by Tilton-on-the-hill (Marlstone); and near Whitton, in Lincolnshire. Prof. Judd mentions that at Halstead the "petrifying springs" have been made use of for the purpose of obtaining incrustations of objects like bird's nests, branching twigs, &c.*

### *Chalybeate Springs.*

Chalybeate Springs, some of which have attained considerable notoriety as Spas, are abundant. Often known as Red Wells (Rodwell, &c.) they issue at various horizons, but appear to be most abundant in the sandy shales at the base of the Marlstone.

#### *Lower Lias.*

Capland Spa, between Ashill and Hatch Beauchamp, N.W. of Ilminster.
Cheltenham: Cambray Spa, (Shallow well).
Little Wolford Hall, S. of Shipston-on-Stour.
Kings Newnham, near Church Lawford, W.N.W. of Rugby.
Brentingby, E. of Melton Mowbray.
Burton Lazars, S.E. of Melton Mowbray.
Little Dalby, S.E. of Melton Mowbray.
Kinoulton Spa, Nottinghamshire. (Saline chalybeate well.)

#### *Middle Lias.*

Glastonbury: Chalice or Blood Well, a spring in the grounds of Tor House. (Yield above 1,000 gallons per hour. Water probably conveyed to supply Holy Well at St. Joseph's Chapel.)
Batheaston Spa, north of Lamb Bridge, near Bath (tepid waters, saline-chalybeate, obtained partly from strata below the Middle Lias). (See p. 323.)

* Geol. Rutland, p. 268.

Shipton-under-Wychwood.
Lower or Nether Worton, S.W. of Deddington.
St. Stephen's Well, on west side of Banbury.
Astrop Spa (Asthorpe, or East-thorpe), King's Sutton, east of Village; water brought in pipes from St. Rumbold's Well. A Saline Chalybeate spring, yielding about 28,000 gallons per day, and containing 51 grains of mineral matter per gallon.
Ilmington Spa, Warwickshire.
Farnborough, near Burton Dassett: St. Botolph's Well.
Thenford, N.W. of Brackley.
Bugbrook, W.S.W. of Northampton.
Barby, N.W. of Daventry.
Denton, S.W. of Grantham.
Lincoln: Monkswell, S.E. of Monk's Abbey. (Spring.)

### *Sulphuretted Springs.*

"Sulphur springs," giving off sulphuretted hydrogen, due to the decomposition of iron-pyrites, are met with here and there in the Liassic clays or shales. These springs are usually more or less saline.

Among those noted are the Daviesville Spa, Burnham, Somerset (derived from a well 25 feet deep, through Alluvium and Lower Lias clay);* spring at Northbrook Farm, Shapwick, west of Glastonbury (Lower Lias); spring at Chilton-upon-Polden, near Edington, Somerset (Lower Lias and Rhætic Beds); the "Black Well" at Queen Camel, north-east of Ilchester; spring at Bowld (or Bould) near Idbury north-west of Burford; and a saline spring at Burton Lazars.†

### *Saline Springs.*

Saline waters occur in most formations, sometimes breaking out at the surface or being proved in shallow wells, but more often being tapped in deeper wells and borings.

Such waters appear to be more often met with in the Lias, a fact to be expected, as the underlying New Red Strata so frequently contain rock-salt and gypsum.

#### *Lower Lias.*

Burnham, Somerset: Daviesville Spa (well 75 feet deep: through Alluvium and Lower Lias clay).
Horton, W. of Ilminster.
Sock Farm, between Yeovil and Ilchester. (Sulphates of lime, magnesia, and soda, chloride of sodium, carbonate of soda, &c.; 217 grains per gallon.)
Alford Well, between Castle Cary and Lovington. (Chloride of sodium, &c.)
Bath: Temp. 109° to 120°. (Sulphates of lime and soda, chlorides of sodium, magnesium, &c. 168 grains per gallon.) (See p. 322.)
Twerton coal-pit, near Bath. (Chloride of sodium; 78 grains per gallon.)
Cherryrock Farm, N.E. of Wickwar (well 40 or 50 feet deep: sulphates of magnesia, soda, and lime, chloride of sodium, &c.).
Coaley, S. of Gloucester (well-waters brackish).
Eastington and Hardwicke, south of Gloucester.
Gloucester: 3 wells, one 80 feet deep. (Chloride of sodium, &c.) (See p. 325.)

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* Notes on the Burnham or Daviesville Spas, by A. C. G. Cameron, Bridgwater Mercury, Jan. 28, 1891.

† Burton Lazars derives its name in part from the Lazar house, or hospital for lepers, which formerly existed there. Judd, Geol. Rutland, p. 270.

Sandhurst, N. of Gloucester.
Bayshill, Cheltenham, and south of Fidler's Green.
Cheltenham: Montpellier Wells (Sulphate of soda, sulphate of magnesia, chloride of sodium, &c.); Pittville Spa (Sulphate of soda, chloride of sodium, &c.). (See p. 323.)
Prestbury and Bishops Cleeve.
Child's Wickham.
Walton Cardiff, Tewkesbury: Walton Spa.
Hampton Spa, Evesham. Wells 11 to 22 feet. (Sulphates of lime, soda, and magnesia, carbonates of magnesia and lime, &c.; 50 grains per gallon).
Evesham. (Saline wells.)
Long Marston (Brine spring.)
Fenny Compton. (Spring, 103 grains per gallon. Sulphate of soda, chloride of sodium, &c.)
Southam Holt, abut 2 miles S.E. of Southam. (Salt spring.)
Willoughby Spa, S.E. of Rugby. (Well sunk 104 feet. Brine spring.)
Shearsby, N.E. of Lutterworth. (Spring, containing chloride of sodium sulphate of soda, &c. 396 grains per gallon). (See p. 325.)
Belvoir Spa, near Belvoir Castle.
Burton Lazars (Chl. sodium.)
Brentingby-cum-Wyfordby, east of Melton Mowbray.
Bracebridge, Lincoln. (Boring 320 feet.) Water containing 593 grains per gallon: 549 chloride of sodium; 11 bromide of sodium; 15 carbonate of soda; 12 carbonate of lime; &c.*

*Middle Lias.*

Dillington, N.E. of Ilminster.
Churchill Mill, between Kingham and Churchill, near Chipping Norton.
Clifton, east of Deddington.
Deddington. (Sulphur saline.)
Sutton Bog, N.E. of railway-station, King's Sutton. (Spring containing sulphate of soda, chloride of sodium, &c. 199 grains per gallon.)
Old Stratford, near Stony Stratford. Well, 110 feet in Marlstone? (Sulphate of lime, carbonate and chloride of sodium, &c. 77 grains per gallon.)
Gumley, N.W. of Market Harborough. (Saline chalybeate.)
Grantham: Spittlegate. (50 grains of mineral matter per gallon.)

Concerning the Bath Waters, the Rev. J. Townsend mentioned that "By Hetlin Court, when the hot springs had failed to supply the usual quantity of water in a given time, the Corporation employed Mr. William Smith to remedy the evil. He laid open the ground, detected the cause of failure, and restored the springs. At that time I took notice of his operations, and at a great depth saw the springs issuing through the blue marl."

"When the new building was constructed over the springs of the Cross Bath, I particularly noticed hot and cold springs issuing within the space of two or three lug of ground, in such a manner that the cold springs were obliged to be separated from the hot ones, and, not being suffered to issue on the spot, were separately conveyed into the river Avon." †

The hot springs rose to the surface not more than 15 or 20 feet above the level of the river. William Smith considered it possible "that the Bath waters may be a compound from the lias, red

* De Rance, Rep. Brit. Assoc. for 1891, p. 302; and Proc. Yorksh. Geol. and Polyt. Soc., vol. xii. p. 49.
† Character of Moses, pp. 197, 313.

rock, coal-measures, and mountain limestone"; * and this view is probably correct. Judging from their temperature, Prof. Prestwich has calculated that the waters rise from a depth of about 3,500 feet; † in this case they may be supported by the Lower Limestone Shales.

It may be mentioned that in sinking a pit in search of coal at Batheaston, warm saline chalybeate waters were encountered.‡ The sinking was carried through Middle and Lower Lias, and the water from the Lias rock, together with that let up by boring the Red rocks beneath, ascended to the surface. I am informed by Mr. W. Topley that, at the present time (1891), the flow from the adit of the old works amounts to about 57,000 gallons a day (40 gallons per minute). The temperature is 62°.

Saline waters have been met with in many localities around Cheltenham, as well as beneath the town.

The Original Spa at Cheltenham "owes its discovery to a slow spring being observed to ooze from a strong thick bluish clay or mould, under the sandy surface of the soil, which, after spreading itself for a few yards, again disappeared, leaving much of its salts behind; flocks of pigeons being daily observed to resort hither to feed on these salts"; and it was "remarked, that when other springs were fast bound by the frost, this continued in a fluid state."§ Thus the water attracted attention about the year 1716. In 1718 the ground was railed in, and the water sold as a medicine. The water for many years was obtained from a well about six feet below the surface, and about 58 gallons were daily pumped up. In 1808 the well was enlarged to 12 feet deep and 6 feet wide.

The temperature of the Cheltenham water varies from 53° to 60°, and it contains the following ingredients:—

| —— | Royal Old Well. | Pittville Spa.‖ |
|---|---|---|
| Chloride of sodium | 590·33 | 481·19 |
| „ magnesium | 8·00 | — |
| Sulphate of soda | 94·94 | 115·82 |
| Carbonate of soda | — | 20·15 |
| „ magnesia | 6·80 | 11·39 |
| „ lime | 17·06 | 7·70 |
| Bromide or iodide of sodium | 3·50 | 3·29 |
| Silica | 2·75 | 2·77 |
| Organic matter, &c. | 18·39 | 3·85 |
| Grains per gallon | 741·77 | 646·16 |

* See Memoirs of W. Smith, pp. 64, &c.

† Geology, Chemical and Physical, p. 166.

‡ Memoirs of W. Smith, pp. 64, &c.; C. Moore, Quart. Journ. Geol. Soc., vol. xxiii. p. 496.

§ G. A. Williams, New Guide to Cheltenham, pp. 20-23, 66, 67.

‖ The original or Royal Old Wells are now closed. They were situated in Montpellier Street. The analyses given, were by Abel and Rowney; see Prestwich, paper read before Ashmolean Soc., Oxford, 1876. A small quantity of potash salts in the Pittville water, is included with the chloride of sodium.

At the Montpellier Wells saline-chalybeate waters were found of somewhat different character in different sinkings. No less than 70 wells were sunk; in most of them chloride of sodium was found to preponderate, but in one case sulphate of magnesia was more abundant. Here the surface-strata comprised about 12 feet of soil and sand, and sinkings were carried to a further depth of 63 feet in the blue clay of the Lias. The water obtained at the greatest depth was more highly chalybeate, and contained a larger proportion of common salt.

With regard to the Cheltenham waters, it was pointed out in 1834 by Murchison, that the most abundant saline ingredient, sea-salt, "is present in still larger quantities in those wells which occur near the western edge of the formation, where the Lias forms only a thin covering above the marls of the New Red Sandstone. At the new spa, near Tewkesbury, where formerly the mineral water at shallow depths below the surface was very slightly saline, it was recently found to be much more impregnated with salt when the sinking was carried to the depth of 90 feet. * * * Again, at Cheltenham, when experimental borings were made by Mr. Thompson, to the depth of 260 feet below the surface, the water of the lowest stratum of marl or clay was found to be more highly charged with the chloride of sodium, or common salt, and to contain less of the sulphates, than the existing wells, none of which have been sunk to a greater depth than 130 feet."

He explains that "waters collected in the New Red Sandstone at higher levels than the surface of the Vale of Gloucester, would naturally ascend to their original level by any cracks or open veins which might present themselves in the overlying Lias. This salt water having to pass through various strata of marl and clay, loaded with iron pyrites, or sulphuret of iron, it is presumed that during this passage certain chemical changes take place, which give to the waters their most valuable medicinal properties." * * * "In suggesting this explanation, we must not, however, overlook the fact, that fresh water is perpetually falling from the atmosphere upon the surface of the Lias clay, more or less percolating its uppermost strata."*

The view suggested by Murchison, that the saline waters of Cheltenham rise from the New Red Sandstone series, is supported by Daubeny, who remarks "that during the passage of the water upwards through cracks and fissures in the Lias clays overlying, the iron pyrites, which is so abundant in that stratum, supplies it by its gradual decomposition with the sulphuric acid found amongst its ingredients. That sulphuretted hydrogen is generated in the vicinity of these springs, we are assured, not

* Murchison, Geol. Cheltenham, 1834, pp. 33–35; Proc. Geol. Soc., vol. i. p. 390; and Silurian System, pp. 34–36.

only from the minute quantities of this gas observed in one or two of the Cheltenham and Leamington waters, but also from the strong impregnation of the spring of Willoughby in Warwickshire."*

Thus, as Dr. Daubeny concludes, the sulphuric acid, acting upon the several chlorides, would form with their bases those earthy and alkaline sulphates on which their medicinal qualities chiefly depend; whilst the free hydrochloric acid disengaged, attacking the calcareous rocks, would give rise to the production of the increased quantity of chloride of lime present in them. He adds that "there is a general impression that the aperient springs, which rise so abundantly from the lias, become weaker when long drawn upon, and it is only in this way that I can reconcile the extreme discrepancy between the analyses of the same spring, at periods not very remote one from the other."

The following analyses of waters from two of the three spa-wells at Gloucester, were made by Mr. George Embrey (1889); they have been communicated by Mr. C. E. Hawkins:—

| — | "Saline Water." | "Sulphurous Water." |
|---|---|---|
| | Grains per gallon. | Grains per gallon. |
| Sodium chloride | 1143·45 | 464·31 |
| Calcium sulphate | 7·19 | 34·00 |
| Calcium carbonate | 32·22 | — |
| Magnesium sulphate | — | 21·33 |
| Magnesium carbonate | 38·58 | 3·23 |
| Iron oxide | ·01 | Trace. |
| Bromine and Iodine | Traces. | — |
| Combined water and loss | 31·55 | 27·13 |
| | 1253·00 | 550·00 |

Traces of Free and Albuminoid Ammonia were found.
The third well is said to yield a strongly ferruginous water.

The saline water obtained from a well at St. Clement's, Oxford, will be referred to more particularly in the volume dealing with the waters obtained from the Oolitic strata.

The Shearsby Spa in Leicestershire originates from a spring about half mile from Shearsby, on the road to Bruntingthorpe. The water rises through the Lower Lias clays, and probably, like the Cheltenham waters, it derives its main ingredients from saliferous Triassic marls. The following analysis by Mr. R. Hayton Davis, has been published by Mr. J. D. Paul:—†

* Rep. Brit. Assoc. for 1836, pp. 13, 19.
† Trans. Leicester Lit. and Phil. Soc., ser. 2, Part III., p. 9.

| | Grains per Imperial gallon. |
|---|---|
| Carbonate of iron | Traces. |
| " lime | 9·743 |
| " magnesia | 6·246 |
| " soda | 5·581 |
| Chloride of sodium | 245·532 |
| Sulphate of soda | 128·989 |
| Chloride of potassium | Traces. |
| Hydrosulphide of sodium | ·275 |
| Iodine and bromine | Traces. |
| | 396·366 |

The origin of these and other saline waters will be more conveniently treated in connexion with the mineral waters of the Oolitic rocks.

# APPENDIX.

## CATALOGUE OF FOSSILS

FROM THE

## LIASSIC ROCKS OF ENGLAND AND WALES.

In preparing the accompanying List of Fossils from the Lias, the attempt has been made to include only the well-authenticated species. In studying the many published papers where lists of fossils are given, it will be noticed that the identification of species by different observers, varies a good deal. Thus in two lists of the more abundant fossils from the same locality, many names do not coincide, when there is every reason to believe that identical species are recorded. This arises in part from the fact that species are variable, and that gradations exist between them. Hence, one authority applies one specific name, and another authority a different specific name to the same fossil. Moreover the synonymy of British and Foreign Liassic fossils requires much attention, and this again is a source of the duplication of names in different lists. Erroneous identifications have also to be guarded against in some of the published lists. The List now given will, it is hoped, be found reliable so far as it goes, the species about which any doubts were felt having been omitted, or inserted with a query.

The species in the Museum of Practical Geology, identified some of them by Mr. Etheridge, some by Messrs. G. Sharman and E. T. Newton, are included in the List. Many additional records from particular localities have been made from the specimens collected by the writer during the progress of his work; and these specimens, excepting some of the commoner forms, have been named by Messrs. Sharman and Newton. Much help has also been given by them, and also by Mr. H. A. Allen during the preparation of this List.

Species recorded in the volumes of the Palæontographical Society, and others preserved in the British Museum of Natural History, in the Woodwardian Museum at Cambridge, and in the University Museum at Oxford, have been noted. Among other Museums it may be mentioned that many Lias fossils are to be seen in the Museums at Taunton, Street near Glastonbury, Bath, Bristol, Cardiff, Gloucester, Worcester, Warwick, Rugby (School), Northampton, and Leicester. Other specimens are preserved in the Dublin Museum of Science and Art.

The fine collection of fossils made by Charles Moore is preserved in the Bath Museum; that of H. E. Strickland (in part), in the Woodwardian Museum; and those made by William Smith, Sowerby, Thomas Hawkins (in part), Sir P. Egerton, the Earl of Enniskillen, Davidson, Wright (in part), and others, are in the British Museum.

Among private collections, especial mention should be made of those formed by the Rev. P. B. Brodie at Rowington, by Mr. T. J. Slatter at Evesham, Mr. R. F. Tomes at South Littleton, near Evesham, Mr. Thomas Beesley

and Mr. E. A. Walford at Banbury, Mr. J. Windoes at Chipping Norton, Mr. Beeby Thompson and Mr. W. D. Crick at Northampton, and Mr. W. D. Carr at Lincoln. From most of these sources, and from published lists of the species, materials have been gathered.

With regard to the perplexing matter of synonymy, much help has been obtained from the British Museum Catalogues of Fossil Vertebrata, by Mr. R. Lydekker and Mr. A. Smith Woodward; and also from the Catalogue of British Fossil Vertebrata, by Messrs. A. S. Woodward and C. D. Sherborn; and the Catalogue of British Jurassic Gasteropoda, by Messrs. W. H. Hudleston and E. Wilson. The last-named Catalogue was issued after the List of Fossils was in type: and it has not been possible to fully revise the nomenclature of the Gasteropods.

The List of Fossils from the Yorkshire Lias, prepared by Mr. Fox-Strangways, and published in the Memoir on the Jurassic Rocks of Yorkshire, has also proved of great service in regard to the synonymy of the Invertebrata. That Memoir (Vol. II.) contains a list of many of the works in which the fossils are figured and described.

The Ammonites are indexed under the generic name *Ammonites*, because confusion must have arisen if any attempt had been made to employ the sub-generic names. These names indeed may be of service to the specialist who confines his attention to Ammonites, but they are of biological, rather than geological importance. Some of the names indeed have been changed again and again since this Memoir was commenced, and many of the species unfortunately are so split up that the multitude of names is simply bewildering, and they become of little or no service to the stratigraphical geologist. In some cases the same specific name has been applied to *mutations* of different sub-genera of Ammonites: a course much to be deprecated, for it is likely that, if accepted as new *species*, the names will eventually be replaced by others. An index to the sub-generic names of Ammonites is given.

The Insects recorded from the Lias require revision; many of the names given are on the authority of C. G. Giebel (Fauna der Vorwelt, 1856, Band 2, Abth. 1.). See also Scudder, Bull. U.S. Geol. Survey, No. 31, 1886, and No. 71, 1891.

For figures of British Liassic Fossils, the student may consult Sowerby's "Mineral Conchology," the works of the Palæontographical Society, "The Yorkshire Lias" by Tate and Blake (1876), and Prestwich's Geology, Vol. ii.

It should be specially noted that the present Catalogue does not enumerate the whole of the Liassic fossils of England and Wales; the species from Yorkshire are given in the Memoir by Mr. Fox-Strangways (above referred to), and only those Yorkshire fossils that occur in the country to the south of the Humber are mentioned in the following lists. To obtain a full record of the Liassic fossils of England and Wales, it will be necessary, therefore, to combine the Catalogue given by Mr. Fox-Strangways with that contained in this volume.

References to Localities given in the accompanying List of Fossils.

| | | | |
|---|---|---|---|
| De. | Devonshire. | Nn. | Northamptonshire. |
| D. | Dorsetshire. | Le. | Leicestershire. |
| S. | Somersetshire. | R. | Rutlandshire. |
| G. | Gloucestershire. | Li. | Lincolnshire. |
| Gl. | Glamorganshire. | Y. | Yorkshire (the references are to the species noted from other counties that occur also in Yorkshire). |
| O. | Oxfordshire. | | |
| Wo. | Worcestershire. | | |
| Wk. | Warwickshire. | | |

The zonal grouping is arranged as follows:—

1. Zone of *Ammonites planorbis.*
2. Zones of *A. angulatus, A. Bucklandi, A. Turneri,* and *A. semicostatus.*
3. Zones of *A. obtusus, A. oxynotus,* and *A. raricostatus.*
4. Zones of *A. armatus, A. Jamesoni,* and *A. Ibex.*
5. Zones of *A. Henleyi,* and *A. capricornus.*
6. Zone of *A. margaritatus.*
7. Zone of *A. spinatus.*
8. "Transition Bed" of Northamptonshire, and Zone of *A. annulatus.*
9. Zone of *A. serpentinus.*
10. Zone of *A. communis.*
11. Zone of *A. jurensis* (passage-beds between Lias and Inferior Oolite)

× Passes up into Inferior Oolite or higher beds; or occurs in the Rhætic Beds below—(according to the column in which placed).

| Species. | Rhætic Beds. | Lower. | | | | | Middle. | | Upper. | | | | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Am. margaritatus. | Am. spinatus. | Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | | | | | |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| **Reptilia.** | | | | | | | | | | | | | | | | | |
| *Ornithosauria.* | | | | | | | | | | | | | | | | | |
| Dimorphodon macronyx, Buckl. | | | | | | | | | | | | | 1 | | | D. | *Pterodactylus* M *deri*, Owen. |
| —— sp. | | | | | | | | | | 9 | | | | | u | G. | *Pterodactylus.* |
| *Dinosauria.* | | | | | | | | | | | | | | | | | |
| Scelidosaurus Harrisoni, Owen. | | | | 3 | | | | | | | | | 1 | | | D. | |
| Zanclodon ? | | | | | | | | | | | | | 1 | | | D. | |
| *Crocodilia.* | | | | | | | | | | | | | | | | | |
| Pelagosaurus typus, Bronn. | | | | | | | | | | 9 | | | | | u | S. G. Y. | *P. temporalis*, Bla |
| Steneosaurus Chapmani, Buckl. | | | | | | | | | | | 10 | | | | u | Nn. Y. | { *Teleosaurus*, *Mystriosaurus.* |
| —— latifrons, Owen. | | | | | | | | | | | | | | | u | × Nn. | |
| *Ichthyopterygia (Ichthyosauria).* | | | | | | | | | | | | | | | | | |
| Ichthyosaurus acutirostris, Owen. | | | | | | | | | | 9 | | | | | u | S. G. Y. | *I. longirostris*, O (pars). |
| —— breviceps, Owen | | | 2 | | | | | | | | | | 1 | | | D. S. | |
| —— communis, Conyb. | | 1 | 2 | | | | | | | | | | 1 | | | D. to Y. | |
| —— Conybearei, Lyd. | × | | | | | | | | | | | | 1 | | | D. S. | |
| —— intermedius, Conyb. | | 1 | 2 | 3 | | | | | | | | | 1 | | | D. to Y. | |
| —— latifrons, Koenig | | | | | | | | | | | ? | | ? | | | D. Le. Y. | *I. longirostris*, O (pars). |
| —— lonchiodon, Owen | | | 2 | | | | | | | | | | 1 | | | D. | |
| —— tenuirostris, Conyb. | | 1 | 2 | | 4 | | | | | | | | 1 | | | D. to Le. | |
| —— setlandicus, Seeley | | | | | | | | | | 9 | | | | | u | G. Le. Y. | *I. longifrons*, Owe |
| —— sp. | | | | | | | | 7 | | | | | | | | S. to Li. | |
| Temnodontosaurus platyodon, Conyb. | × | 1 | 2 | 3 | | | | | | | | | 1 | | | D. to Y. | *Ichthyosaurus.* |
| *Sauropterygia (Plesiosauria).* | | | | | | | | | | | | | | | | | |
| Eretmosaurus rugosus, Owen. | × | 1 | 2 | 3 | | | | | | | | | | | | D. to Y. | *Plesiosaurus.* |
| Plesiosaurus compressus, Owen. | | | | | | | | | | | | | 1 | | | S. | |
| —— Conybearei, Sollas | | | | 3 | | | | | | | | | 1 | | | D. | |
| —— (*near to*) Dewalquei, Van Ben. | | | | | | | | | | | | | 1 | | | Le. | |
| —— dolichodirus, Conyb. | | 1 | | | | | | | | | | | 1 | | | D. S. N. | *P. cliduchus*, Seel |
| —— eleutheraxon, Seeley | | 1 | | | | | | | | | | | 1 | | | S. | |
| —— Hawkinsi, Owen | × | 1 | | | | | | | | | | | 1 | | | D. to Le. | *P. Etheridgei*, Hu |

| SPECIES. | Rhætic Beds. | Lower. Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Middle. Am. margaritatus. | Am. spinatus. | Upper. Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | Lower | Middle Lias. | Upper Lias. | LOCALITIES. | REMARKS. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| REPTILIA—*cont.* | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| *ropterygia* (*Plesiosauria*)—cont. | | | | | | | | | | | | | | | | | |
| saurus macrocepha- Conyb. | | 1 | 2 | | | | | | | | | | 1 | | u | D. to Y. - | *P. brachycephalus*, Ow. |
| acromus, Owen - | | | | | | | | | | | | | 1 | | | D. | |
| atydirus, Owen - | | | | | | | | | | | | | 1 | | | D. | |
| stratus, Owen - | | | 2 | | | | | | | | | | 1 | | | D. | |
| bconcavus, Owen - | | | | | | | | | | | | | 1 | | | S. | |
| btrigonus, Owen - | | | 2 | | | | | | | | | | 1 | | | S. | |
| p. - - - | | | | | | | | | | 9 | | 11 | | | u | G. Nn. Li. | |
| natosaurus arcuatus, n. | | 1 | | | | | | | | | | | 1 | | | D. S. G. - | *Plesiosaurus.* |
| egacephalus, Stutch. | | 1 | 2 | | | | | | | | | | 1 | | | S. Wk. | |
| ropinquus, Blake - | | | | | | | | | | 9 | | | | m | | Nn. Y. | |
| PISCES. | | | | | | | | | | | | | | | | | |
| *Ganoidei.* | | | | | | | | | | | | | | | | | |
| *odus*, see Dapedius. | | | | | | | | | | | | | | | | | |
| *urus*, see Dapedius. | | | | | | | | | | | | | | | | | |
| rhynchus acutus, | | 1 | | | | | | | | | | | 1 | | | D. - - | *Belonostomus Anningiæ*, Ag. *B. tenellus*, Ag. |
| eichthys ornatus, . Woodw. | | 1 | | | | | | | | | | | 1 | | | Le. | |
| olepis aspera, Eg. - | | | | | | | | | | | | | 1 | | | D. | |
| rosteus acipense- es, Ag. | | 1 | | 3 | | | | | | | | | 1 | | | D. Le. - | *C. crassior*, Eg. |
| achyurus, Eg. - | | | | | | | | | | | | | 1 | | | D. | |
| lepis liassica, A. S. odw. | | | | | | | | | | | | | 1 | | | D. | |
| *lus*, see Eugnathus. | | | | | | | | | | | | | | | | | |
| *olepis*, see Oxygna- s. | | | | | | | | | | | | | | | | | |
| lius angulifer, Ag. - | | 1 | | | | | | | | | | | 1 | | | Wk. | *Æchmodus*, *Tetragonolepis.* |
| olei, Ag. - - | | | | | | | | | | | | | 1 | | | D. | |
| orsalis, Ag. - - | | 1 | 2 | | | | | | | | | | 1 | | | S. G. ? Le. - | *Tetragonolepis* m*nilifer*, Ag. *Tetrag. striolat*, Ag. |
| ranulatus, Ag. - | | | | 3 | | | | | | | | | 1 | | | D. - - | *Æch. pustulatus*, A |
| eachi, Ag. - - | | | | 3 | | | | | | | | | 1 | | | D. - - | *Pholidotus*, *Tetrag. striatus*, Ag |
| iosomus, Ag. - - | | | | | | | | | | | | | 1 | | | D. | |

| Species. | Rhætic Beds. | Lower. Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Middle. Am. margaritatus. | Am. spinatus. | Upper. Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pisces—*cont.* | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| *Ganoidei*—cont. | | | | | | | | | | | | | | | | | |
| Dapedius orbicularis, Morris. | | | | | | | | | | | | | 1 | | | D. | |
| —— orbis, Ag. | | 1 | | | | | | | | | | | 1 | | | Wk. Le. | |
| —— pholidotus, Ag. | | | | | | | | | | | | | 1 | | | D. | *Æchmodus.* |
| —— politus, De la Beche | | | | | | | | | | | | | 1 | | | D. | *Æchmodus confl* Ag. |
| —— punctatus, Ag. | | | | | | | | | | | | | 1 | | | D. | *Æch. speciosus*, A |
| —— radiatus, Ag. | | | | | | | | | | | | | 1 | | | D. | |
| —— sp. | | | | | | | | | | | | | 1 | | | D. | *Amblyurus ma stomus*, Ag. (Crushed s men A. Woodward) |
| Endactis Agassizi, Eg. | | | | | | | | | | | | | 1 | | | D. | |
| Eugnathus latus, Eg. | | | | | | | | | | | | | 1 | | | D. | *Heterolepidotus*, *Semionotus rh fer ?*, Ag. |
| —— minor, Ag. | | | | | | | | | | | | | 1 | | | D. | |
| —— opercularis, Ag. | | | | | | | | | | | | | 1 | | | D. | (Specimen not kn |
| —— orthostomus, Ag. | | | | | | | | | | | | | 1 | | | D. | *E. scabriusculus* *E. speciosus*, A |
| —— Philpotæ, Ag. | | | | | | | | | | | | | 1 | | | D. | *Heterolep. sauro* Eg. |
| —— serratus, Davis | | | | | | | | | | | | | 1 | | | D. | *Lissolepis.* |
| —— serrulatus, Ag. | | 1 | | | | | | | | | | | 1 | | | Le. | *Lepidotus.* |
| —— ? chirotes, Ag. | | | | | | | | | | | | | 1 | | u | D. S. | *Conodus ferox*, A |
| —— see also Platysiagum. | | | | | | | | | | | | | | | | | |
| Harpactira velox, Eg. | | | | | | | | | | | | | 1 | | | D. | *Harpactes.* |
| *Holophagus*, see Undina. | | | | | | | | | | | | | | | | | |
| Isocolum granulatum, Eg. | | | | | | | | | | | | | 1 | | | D. | |
| Lepidotus elvensis, Quenst. | | | | | | | | | | 9 | | | | | u | Nn. | *L. gigas*, Ag. |
| —— rugosus, Ag. | | | | 3 | | | | | | 9 | | | 1 | | u | D. Y. | |
| —— sp. | | | | | | | | 7 | | | | | | m | u | S. | |
| Leptolepis Bronni, Ag. | | | | | | | | | | | | | 1 | | u | D. S. | |
| —— caudalis, Ag. | | | | | | | | | | | | | 1 | | | D. | |
| —— concentricus, Eg. | | 1 | | | | | | | | 9 | | | 1 | | u | Le. S. G. Nn. | non *L. sprattif de Blainv.* |
| —— constrictus, Eg. | | | | | | | | | | 9 | | | | | u | S. G. | |
| *Lissolepis*, see Eugnathus. | | | | | | | | | | | | | | | | | |
| Mesodon liassicus, Eg. | | 1 | | | | | | | | | | | 1 | | | G. Le. | |
| Nothosomus octostychius, Ag. | | | | | | | | | | | | | 1 | | | D. S. | |

| Species. | Rhætic Beds. | Lower. | | | | | Middle. | | Upper. | | | | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Am. margaritatus. | Am. spinatus. | Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | | | | | |
| **Pisces**—*cont.* | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| *?anoidei*—cont. | | | | | | | | | | | | | | | | | |
| achis macrocephala, | | | | | | | | | | | | | 1 | | | D. | |
| athus Egertoni, Eg. | | | | | | | | | | | | | 1 | | | Le. - - | *Cosmolepis.* |
| mtus, Eg. - - | | | | | | | | | | | | | 1 | | | D. - - | *Thrissonotus C* |
| ormus curtus, Ag. - | | | | | | | | | | 9 | | | | | u | S. Y. | |
| terurus, Ag. - - | | | | 3 | | | | | | | | | 1 | | | D. | |
| tipennis, Ag. - - | | | | | | | | | | | | | 1 | | ? | D. S.? | |
| acropterus, Ag. - | | | | | | | | | | 9 | | | | | u | S. Y. | |
| acrurus, Ag. - - | | | | | | | | | | | | | 1 | | | D. | |
| *lotus*, see Dapedius. | | | | | | | | | | | | | | | | | |
| ophorus crenulatus, | | | | | | | | | | | | | 1 | | | D. | |
| De la] Bechei, Ag. - | | | | | | | | | | | | | 1 | | | D. - - | Common. |
| astingsiæ, Ag. - | | 1 | | | | | | | | | | | 1 | | | Le. | |
| tiusculus, Ag. - | | | | | | | | | | | | | 1 | | | D. | |
| abatus, Ag. - - | | | | | | | | | | | | | 1 | | | D. | |
| ychius, Ag. - - | | | | | | | | | | | | | 1 | | | D. | |
| chysomus, Eg. - | | | | | | | | | | | | | 1 | | | D. | |
| tricklandi, Ag. - | | 1 | | | | | | | | | | | 1 | | | Wk. Le. | |
| ). - - - - | | | | | | | | | | | | | | | u | S. | |
| iagum grandis, Davis | | | | | | | | | | | | | 1 | | | D. | |
| lerocephalum, Eg. - | | | | | | | | | | | | | 1 | | | D. - - | *Eugnathus po* Ag. |
| olepis bollensis, Ag. - | | | | | | | | | | 9 | | | 1 | | u | D. Y. | |
| urtus, Eg. - - | | | | | | | | | | | | | 1 | | | D. | |
| racilis, Davis - - | | | | | | | | | | | | | 1 | | | D. | |
| inor, Eg. - - | | 1 | | | | | | | | | | | 1 | | | Le. | |
| gonolepis discus, Eg. | | | | | | | | | | 9 | | | 1 | | u | D. G. | |
| e also Dapedius. | | | | | | | | | | | | | | | | | |
| *sonotus*, see Oxygnathus. | | | | | | | | | | | | | | | | | |
| a barroviensis, A. S. Wodw. | | | | | | | | | | | | | 1 | | | Le. | |
| ulo, Eg. - - | | | | | | | | | | | | | 1 | | | D. - - | *Holophagus.* |
| *Elasmobranchii.* | | | | | | | | | | | | | | | | | |
| lus Anningiæ, Ag. - | | | | | | | | | | | | | 1 | | | D. - - | *A. undulatus*, . |
| obilis, Buckl. - - | | | 2 | | | | | | | | | | 1 | | | D. S. - | { *A. gibberulus*, *A. latus*, A |

| Species. | Rhætic Beds. | Lower. Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Middle. Am. margaritatus. | Am. spinatus. | Upper. Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| Pisces—*cont.* | | | | | | | | | | | | | | | | | |
| *Elasmobranchii*—cont. | | | | | | | | | | | | | | | | | |
| Arthropterus Rileyi, Ag. - | | | | | | | | | | | | | 1 | | | D. S. G. | |
| Cyclarthrus macropterus, Ag. | | | | | | | | | | | | | 1 | | | D | |
| Hybodus carinatus, Ag. - | | | | | | | | | | | | | 1 | | | D. - - | *Acrodus Anningi* |
| —— crassispinus Ag. - | | | | | | | | | | | | | 1 | | | D. | |
| —— Dolabechei, Charlesworth. | | | | 3 | | | | | | | | | 1 | | | D. - - | *H. pyramidalis,* |
| —— ensatus, Ag. - - | | | | | | | | | | | | | 1 | | | D. | |
| —— medius, Ag. - - | | | | | | | | | | | | | 1 | | | D. | |
| —— raricostatus, Ag. - | | | | | | | | | | | | | 1 | | | D. | |
| —— reticulatus, Ag. - | × | | 2 | | | | | | | | | | 1 | | | D. Y. - | Common. |
| —— sp. - - - | | | | | | | 6 | 7 | 8 | | | | | m | u | D. S. O. Li. | |
| Palæospinax priscus, Ag. - | | | | | | | | | | | | | 1 | | | D. - - | *Thyellina.* |
| Sphenonchus hamatus, Ag. | | | | | | | | | | | | | 1 | | | D. S. | |
| *Holocephali.* | | | | | | | | | | | | | | | | | |
| Myriacanthus granulatus, Ag. | | | | | | | | | | | | | 1 | | | D. - - | { *Chimæra. Isch orthorhinus, Leptacanthus t pinus,* Ag. |
| —— paradoxus, Ag. - | | | | | | | | | | | | | 1 | | | D. - - | { *I. Johnsoni,* Ag. *Prognathodu theri,* Eg. *M. retroversus,* |
| Squaloraja polyspondyla, Ag. | | | | | | | | | | | | | 1 | | | D. | |
| —— tenuispina, A. S. Woodw. | | | | | | | | | | | | | 1 | | | D. | |
| Mollusca. | | | | | | | | | | | | | | | | | |
| *Cephalopoda.* | | | | | | | | | | | | | | | | | |
| Ammonites acutus, Tate - | | | | | | | | 7 | 8 | | | | | m | u | O. Nn. Le. - | *Harpoceras.* |
| —— affinis, Seeb. - - | | | | | | | | | | | | 11 | | | u | × G. Y. - | *Hudlestonia.* |
| —— angulatus, Schloth. - | | | 2 | | | | | | | | | | 1 | | | D. to Y. - | *Ægoceras, Schl simia.* |
| —— annulatus, Sow. - | | | | | | | | 7 | 8 | 9 | 10 | | | m | u | D. to Y. - | { *Stephanoceras, Cœloceras.* |
| —— aratus, S. Buckm. - | | | | | | | | | | | | 11 | | | u | × G. - | { *Dumortieria, Catulloceras.* |
| —— armatus, Sow. - - | | | | 3 | 4 | | | | | | | | 1 | | | D. to Y. - | *Ægoceras.* |
| —— [De la] Bechei, Sow. - | | | | | | 5 | 6 | 7 | | | | | 1 | m | | D. to Y. - | *Ægoceras.* |
| —— *Belcheri,* Simps. = var. of A. Johnstoni. | | | | | | | | | | | | | | | | | |
| —— bicarinatus, Münst. - | | | | | | | | | | | | 11 | | | u | S. G. - | *Harpoceras.* |
| —— bifer, Quenst. - - | | | | 3 | 4 | | | | | | | | 1 | | | S. G. Wk. | |

| Species. | Rhætic Beds. | Lower. | | | | | Middle. | | Upper. | | | | | | | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Am. margaritatus. | Am. spinatus. | Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | Lower Lias. | Middle Lias. | Upper Lias. | | |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| ollusca—*cont.* | | | | | | | | | | | | | | | | | |
| *phalopoda*—cont. | | | | | | | | | | | | | | | | | |
| nites bifrons, Brug. | | | | | | | | | 8 | 9 | 10 | 11 | | m | u | D. to Y. - | *A. Walcotti*, Sow. *Harpoceras, Hildoceras.* |
| irchii, Sow. - - | | | 2 | 3 | | | | | | | | | 1 | | | D. to Y. - | *Ægoceras.* |
| sulcatus, Brug. - | | | 2 | 3 | | | | | | | | | 1 | | | D. to Y. - | *A. multicostata*, Sow. *Arietites.* |
| onnardi, d'Orb. - | | | 2 | 3 | | | | | | | | | 1 | | | D. G. Y. - | *Arietites.* |
| oreale, Seeb. - - | | | | | | | | | | 9 | | | | | | Nn. - - | *Harpoceras, Hildoceras.* |
| aunianus, d'Orb. - | | | | | | | | | | | 10 | 11 | | | u | G. Nn. Y. - | *Stephanoceras.* |
| revispina, Sow. - | | | | 3 | 4 | | | | | | | | 1 | | | D. to Y. - | *Ægoceras.* |
| rookei, Sow. - - | | | 2 | 3 | | | | | | | | | 1 | | | D. S. Wk. Y. | *Arietites.* |
| ucklandi, Sow. - | | | 2 | | | | | | | | | | 1 | | | D. to Y. - | *Arietites.* |
| uvignieri, d'Orb. - | | | | | 4 | | | | | | | | 1 | | | S. Wk. - | *Phylloceras.* |
| ecilia, Rein. - - | | | | | | | | 7 | | 9 | 10 | | | m | u | O. Nn. Y. | |
| apricornus, Schloth. - | | | | | | 5 | 6 | | | | | | 1 | m | | D. to Y. (m) | *A. maculatus*, Y. & B. *Ægoceras.* |
| atenatus, d'Orb. - | | | 2 | | | | | | | | | | 1 | | | Le. Li. - | *Ægoceras, Schlotheimia.* Var. of *A. angulatus.* |
| harmassei, d'Orb. - | | | 2 | | | | | | | | | | 1 | | | D. G. Le. Li. Y. | *A. boucaultianus*, d'Orb. *Ægoceras, Schlotheimia.* Near to *A. angulatus.* |
| omensis, Von Buch. - | | | | | | | | | | | | 11 | | | u | G. Y. | |
| ommunis, Sow. - | | | | | | | | 7 | 8 | 9 | 10 | | | m | u | D. to Y. - | *Stephanoceras, Cœloceras.* |
| ompactilis, Simps. - | | | | | | | | | | | | 11 | | | u | G. Y. - | *Harpoceras, Pseudolioceras.* |
| *omplanatus*, d'Orb., see A. subplanatus, Oppel. | | | | | | | | | | | | | | | | | |
| onybearei, Sow. - | | | 2 | | | | | | | | | | 1 | | | D. to Y. - | *Arietites.* |
| ornucopia, Y. & B. - | | | | | | | | | 8 | 9 | 10 | | | | u | G. to Y. - | *Lytoceras.* |
| ostula, Rein. - - | | | | | | | | | | | | 11 | | | u | × G. - | *Harpoceras. Dumortieria.* |
| otteswoldiæ, S. Buckm. | | | | | | | | | | | | 11 | | | u | G. - - | *Grammoceras.* |
| rassus, Y. & B. - | | | | | | | | 7 | 8 | 9 | 10 | | | m | u | D. to Y. - | *A. raquinianus*, d'Orb. *Stephanoceras, Cœloceras. Dactyloceras.* |
| rossi, Wright - | | | 2 | | | | | | | | | | 1 | | | Li. - - | *Arietites.* |
| urvicornis, Schloen. - | | | | 3 | 4 | 5 | | | | | | | 1 | | | D. Le. - | *Ægoceras.* |
| Davoei, Sow. - - | | | | | | 5 | | | | | | | 1 | | | D. S. G. O. - | *Ægoceras.* |
| lensinodus, Quenst. - | | | | 3 | 4 | | | | | | | | 1 | | | D. G. Wk. Y. | *A. obsoletus*, Simps. *Ægoceras.* |

| Species. | Rhætic Beds. | Lower. | | | | | Middle. | | Upper. | | | | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Am. margaritatus. | Am. spinatus. | Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | | | | | |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| **Mollusca**—*cont.* | | | | | | | | | | | | | | | | | |
| *Cephalopoda*—cont. | | | | | | | | | | | | | | | | | |
| Ammonites Desplacei, d'Orb. | | | | | | | | | | 9 | 10 | | | | u | Nn. Li. Y. - | *Stephanoceras.* |
| —— discoides, Ziet. - | | | | | | | | | | | | 11 | | | u | × S. G. - | *Harpoceras.* *Polyplectus.* |
| —— dispansus, Lyc. | | | | | | | | | | | | 11 | | | u | × D. S. G. Li. | *Harpoceras.* Near to *A.* … *bilis*, d'Orb. *Grammoceras* |
| —— doerntensis, Denckm. | | | | | | | | | | | | 11 | | | u | G. - - | *Grammoceras.* |
| —— *Dudressieri*, d'Orb., see A. planicosta. | | | | | | | | | | | | | | | | | |
| —— Dumortieri, S. Buckm. | | | | | | | | | | | | 11 | | | u | G. - - | *Haugia.* |
| —— —— Thioll. - | | | | | | | | | | | | 11 | | | u | × D. S. - | *Catulloceras.* |
| —— elegans, Y. & B. - | | | | | | | | | 8 | 9 | 10 | | | | u | Nn. to Y. - | *Harpoceras.* |
| —— Engelhardti, d'Orb. - | | | | | | | | 7 | | | | | | m | | S. G. Nn. Y. | *Amaltheus.* |
| —— Eseri, Oppel - | | | | | | | | 7 | | | | 11 | | m | u | D. O. G. - | *Haugia.* |
| —— exaratus, Y. & B. - | | | | | | | | | 8 | 9 | 10 | | | | u | O. to Y. - | *Harpoceras.* |
| —— falcifer, Sow. - | | | | | | | | | 8 | 9 | | | | | u | G. to Y. - | *Harpoceras.* |
| —— fallaciosus, Bayle | | | | | | | | | | | | 11 | | | u | S. G. - | *Grammoceras.* |
| —— fibulatus, Sow. | | | | | | | | | | | 10 | | | | u | O. to Y. - | *Stephanoceras.* |
| —— fimbriatus, Sow. | | | | | 4 | 5 | 6 | 7 | | | | | | m | ? | D. to Y. - | *A. lineatus*, Schl… *Lytoceras.* |
| —— fonticulus, Simps. | | | | | | | | | 8 | 9 | | | | | u | O. Nn. Y. - | *Stephanoceras.* |
| —— gagateus, Y. & B. | | | | 3 | | 5 | | | | | | | l | | | Le. Y. - | *Ægoceras.* |
| —— *geometricus*, Oppel., see A. semicostatus. | | | | | | | | | | | | | | | | | |
| —— Greenoughi, Sow. | | | 2 | 3 | | | | | | | | | l | | | D. G. Y. - | *Amaltheus.* *Phylloceras.* |
| —— guibalianus, d'Orb. | | | | 3 | 4 | | | | | | | | l | | | D. to Wk. - | *Amaltheus.* |
| —— Henleyi, Sow. - | | | | | 4 | 5 | | | | | | | l | | | D. to Y. - | Near to *A. stria*… *Ægoceras.* |
| —— heterogenes, Y. & B. - | | | | | 4 | 5 | | | | | | | l | | | D. Y. - | *Ægoceras.* |
| —— heterophyllus, Sow. - | | | | | | | | 7 | 8 | 9 | 10 | | | m | u | D. to Y. - | *Phylloceras.* |
| —— hircinus, Schloth. | | | | | | | | | | | | 11 | | | u | × D. G. Y. - | *Lytoceras, A. Leckenbyi*, Ly… |
| —— Holandrei, d'Orb. | | | | | | | | 7 | 8 | 9 | 10 | | | m | u | D. to Y. - | *Stephanoceras.* *Dactylioceras.* |
| —— Ibex, Quenst. - | | | | | 4 | | | | | | | | l | | | S.G.Wk.Nn. | *A. Boblayei*, d'O… *Amaltheus.* |
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| —— Birchii, Sow. - - | | | 2 | 3 | | | | | | | | | 1 | | | D. to Y. - | *Ægoceras.* |
| —— bisulcatus, Brug. - | | | 2 | 3 | | | | | | | | | 1 | | | D. to Y. - | *A. multicostata*, Sow. *Arietites.* |
| —— Bonnardi, d'Orb. - | | | 2 | 3 | | | | | | | | | 1 | | | D. G. Y. - | *Arietites.* |
| —— boreale, Seeb. - - | | | | | | | | | | 9 | | | | | | Nn. - - | *Harpoceras, Hildoceras.* |
| —— braunianus, d'Orb. - | | | | | | | | | | | 10 | 11 | | | u | G. Nn. Y. - | *Stephanoceras.* |
| —— brevispina, Sow. - | | | | 3 | 4 | | | | | | | | 1 | | | D. to Y. - | *Ægoceras.* |
| —— Brookei, Sow. - - | | | 2 | 3 | | | | | | | | | 1 | | | D. S. Wk. Y. | *Arietites.* |
| —— Bucklandi, Sow. - | | | 2 | | | | | | | | | | 1 | | | D. to Y. - | *Arietites.* |
| —— Buvignieri, d'Orb. - | | | | | 4 | | | | | | | | 1 | | | S. Wk. - | *Phylloceras.* |
| —— cæcilia, Rein. - - | | | | | | | | 7 | | 9 | 10 | | | m | u | O. Nn. Y. | |
| —— capricornus, Schloth. - | | | | | | 5 | 6 | | | | | | 1 | m | | D. to Y. (m) | *A. maculatus*, Y. & B. *Ægoceras.* |
| —— catenatus, d'Orb. - | | | 2 | | | | | | | | | | 1 | | | Le. Li. - | *Ægoceras, Schlotheimia.* Var. of *A. angulatus.* |
| —— Charmassei, d'Orb. - | | | 2 | | | | | | | | | | 1 | | | D. G. Le. Li. Y. | *A. boucaultianus*, d'Orb. *Ægoceras, Schlotheimia.* Near to *A. angulatus.* |
| —— comensis, Von Buch. - | | | | | | | | | | | | 11 | | | u | G. Y. | |
| —— communis, Sow. - | | | | | | | | 7 | 8 | 9 | 10 | | | m | u | D. to Y. - | *Stephanoceras, Cœloceras.* |
| —— compactilis, Simps. - | | | | | | | | | | | | 11 | | | u | G. Y. - | *Harpoceras, Pseudolioceras.* |
| —— *complanatus*, d'Orb., see A. subplanatus, Oppel. | | | | | | | | | | | | | | | | | |
| —— Conybearei, Sow. - | | | 2 | | | | | | | | | | 1 | | | D. to Y. - | *Arietites.* |
| —— cornucopia, Y. & B. - | | | | | | | | | 8 | 9 | 10 | | | | u | G. to Y. - | *Lytoceras.* |
| —— costula, Rein. - - | | | | | | | | | | | | 11 | | | u | × G. - | *Harpoceras. Dumortieria.* |
| —— cotteswoldiæ, S. Buckm. | | | | | | | | | | | | 11 | | | u | G. - - | *Grammoceras.* |
| —— crassus, Y. & B. - | | | | | | | | 7 | 8 | 9 | 10 | | | m | u | D. to Y. - | *A. raquinianus*, d'Orb. *Stephanoceras, Cœloceras. Dactyloceras.* |
| —— Crossi, Wright - | | | 2 | | | | | | | | | | 1 | | | Li. - - | *Arietites.* |
| —— curvicornis, Schloen. - | | | | 3 | 4 | 5 | | | | | | | 1 | | | D. Le. - | *Ægoceras.* |
| —— Davoei, Sow. - - | | | | | | 5 | | | | | | | 1 | | | D. S. G. O. - | *Ægoceras.* |
| —— densinodus, Quenst. - | | | | 3 | 4 | | | | | | | | 1 | | | D. G. Wk. Y. | *A. obsoletus*, Simps. *Ægoceras.* |

| Species. | Rhætic Beds. | Lower. Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Middle. Am. margaritatus. | Am. spinatus. | Upper. Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mollusca**—*cont.* | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| *Cephalopoda*—cont. | | | | | | | | | | | | | | | | | |
| Ammonites Desplacei, d'Orb. | | | | | | | | | | 9 | 10 | | | | u | Nn. Li. Y. - | *Stephanoceras.* |
| —— discoides, Ziet. - | | | | | | | | | | | | 11 | | | u | × S. G. - | *Harpoceras. Polyplectus.* |
| —— dispansus, Lyc. | | | | | | | | | | | | 11 | | | u | × D. S. G. Li. | *Harpoceras.* Near to *A. va bilis*, d'Orb. *Grammoceras.* |
| —— doerntensis, Denckm. | | | | | | | | | | | | 11 | | | u | G. - - | *Grammoceras.* |
| —— *Dudressieri*, d'Orb., see A. planicosta. | | | | | | | | | | | | | | | | | |
| —— Dumortieri, S. Buckm. | | | | | | | | | | | | 11 | | | u | G. - - | *Haugia.* |
| —— —— Thioll. - - | | | | | | | | | | | | 11 | | | u | × D. S. - | *Catulloceras.* |
| —— elegans, Y. & B. - | | | | | | | | | 8 | 9 | 10 | | | | u | Nn. to Y. - | *Harpoceras.* |
| —— Engelhardti, d'Orb. - | | | | | | | | 7 | | | | | | m | | S. G. Nn. Y. | *Amaltheus.* |
| —— Eseri, Oppel - - | | | | | | | | 7 | | | | 11 | | m | u | D. O. G. - | *Haugia.* |
| —— exaratus, Y. & B. - | | | | | | | | | 8 | 9 | 10 | | | | u | O. to Y. - | *Harpoceras.* |
| —— falcifer, Sow. - - | | | | | | | | | 8 | 9 | | | | | u | G. to Y. - | *Harpoceras.* |
| —— fallaciosus, Bayle - | | | | | | | | | | | | 11 | | | u | S. G. - | *Grammoceras.* |
| —— fibulatus, Sow. - | | | | | | | | | | | 10 | | | | u | O. to Y. - | *Stephanoceras.* |
| —— fimbriatus, Sow. - | | | | | 4 | 5 | 6 | 7 | | | | | | m | ? | D. to Y. - | *A. lineatus*, Schlot. *Lytoceras.* |
| —— fonticulus, Simps. - | | | | | | | | | 8 | 9 | | | | | u | O. Nn. Y. - | *Stephanoceras.* |
| —— gagateus, Y. & B. - | | | | 3 | | 5 | | | | | | | l | | | Le. Y. - | *Ægoceras.* |
| —— *geometricus*, Oppel., see A. semicostatus. | | | | | | | | | | | | | | | | | |
| —— Greenoughi, Sow. - | | | 2 | 3 | | | | | | | | | l | | | D. G. Y. - | *Amaltheus. Phylloceras.* |
| —— guibalianus, d'Orb. - | | | | 3 | 4 | | | | | | | | l | | | D. to Wk. - | *Amaltheus.* |
| —— Henleyi, Sow. - - | | | | | 4 | 5 | | | | | | | l | | | D. to Y. - | Near to *A. striatu Ægoceras.* |
| —— heterogenes, Y. & B. - | | | | | 4 | 5 | | | | | | | l | | | D. Y. - | *Ægoceras.* |
| —— heterophyllus, Sow. - | | | | | | | | 7 | 8 | 9 | 10 | | | m | u | D. to Y. - | *Phylloceras.* |
| —— hircinus, Schloth. - | | | | | | | | | | | | 11 | | | u | × D. G. Y. - | *Lytoceras, A. Leckenbyi*, Lyc. |
| —— Holandrei, d'Orb. - | | | | | | | | 7 | 8 | 9 | 10 | | | m | u | D. to Y. - | *Stephanoceras. Dactyloceras.* |
| —— Ibex, Quenst. - - | | | | | 4 | | | | | | | | l | | | S.G.Wk.Nn. | *A. Boblayei*, d'Orb. *Amaltheus.* |
| —— illustris, Denckm. - | | | | | | | | | | | | 11 | | | u | G. - - | *Haugia.* |
| —— impendens, Y. & B. - | | | | 3 | | | | | | | | | l | | | G. Y. - | *Aristites.* |
| —— insignis, Schübl. - | | | | | | | | | | | 10 | 11 | | | u | ×D. S. G. Y. | *Harpoceras. Hammatoceras.* |
| —— insigni-similis, Brauns | | | | | | | | | | | | 11 | | | u | G. - - | *Catulloceras.* |
| —— *intermedius*, Portl. = var. of A. Johnstoni. | | | | | | | | | | | | | | | | | |
| —— Jamesoni, Sow. - | | | | | 4 | | | | | | | | l | | | D. to Y. - | *Ægoceras.* |

| Species. | Rhætic Beds. | Lower. | | | | | Middle. | | Upper. | | | | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Am. margaritatus. | Am. spinatus. | Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | | | | | |
| MOLLUSCA—*cont.* | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| *Cephalopoda*—cont. | | | | | | | | | | | | | | | | | |
| Ammonites Johnstoni, Sow. | | 1 | 2 | | | | | | | | | | 1 | | | D. to Y. - | *A. torus*, d'Orb. *Ægoceras.* |
| — jugosus, Sow. - - | | | | | | | | | | | | 11 | | | u | D. G. - | *Haugia.* Near to *A. variabilis.* |
| — jurensis, Ziet. - - | | | | | | | | | | | | 11 | | | u | D. S. G. Y. | *Lytoceras.* |
| — lacunatus, Buckm. - | | | 2 | 3 | | | | | | | | | 1 | | | G. Y. - | *Ægoceras.* |
| — lævigatus, Sow. - | | | | | 4 | | | | | | | | 1 | | | D. G. | |
| — laqueolus, Schlön. - | | 1 | 2 | | | | | | | | | | 1 | | | S. G. Le. Li. Y. | *A. tortilis*, d'Orb. *Ægoceras.* |
| — latæcosta, Sow. | | | | | 4 | 5 | | | | | | | 1 | | | D. S. G. Li. | *Ægoceras.* |
| — latescens, Simps. - | | | | | | | | | | | 9 | | | | u | O. Nn. Y. - | *A. Sæmanni*, Oppel. *Harpoceras.* |
| — Leckenbyi, Wright - | | | | | 4 | | | | | | | | 1 | | | D. - - | *Ægoceras* (non *A. Leckenbyi*, Lyc. See *A. hircinus.*) |
| — Leesbergi, Branco - | | | | | | | | | | | | 11 | | | u | × G. - | *Catulloceras.* |
| — Levesquei, d'Orb. - | | | | | | | | | | | | 11 | | | u | D. S. G. - | *Harpoceras. Dumortieria.* |
| — Levisoni, Simps. - | | | | | | | | | 8 | 9 | 10 | | | | | S. to Y. - | *Harpoceras. Hildoceras.* |
| — Lilli, Dum. - - | | | | | | | | | | | | 11 | | | u | N. | |
| — *lineatus*, Schloth, see A. fimbriatus. | | | | | | | | | | | | | | | | | |
| — Loscombei, Sow. - | | | | | 4 | 5 | 6 | | | | | | 1 | | | D. to Y. - | *Phylloceras.* |
| — lymensis, Wright - | | | | 3 | | | | | | | | | 1 | | | D. - - | Near *A. oxynotus. Amaltheus.* |
| — lympharum, Dum. - | | | | | | | | | | | | 11 | | | u | Nn. - | *Harpoceras.* |
| — lythensis, Y. & B. - | | | | | | | | | | 9 | 10 | | | | u | G. to Y. - | *Harpoceras.* |
| — margaritatus, Mont. - | | | | | | | 6 | 7 | | | | | | m | | D. to Y. - | *Amaltheus.* |
| — Maugenesti, d'Orb. - | | | | | 4 | 5 | | | | | | | 1 | | | D. to Y. - | *Ægoceras.* |
| — metallarius, Dum. - | | | | | | | | | | | | 11 | | | u | G. - - | *Grammoceras.* |
| — moreanus, d'Orb. - | | | 2 | | | | | | | | | | 1 | | | D. - - | Var. of *A. angulatus. Ægoceras.* |
| — Muelleri, Denckm. - | | | | | | | | | | | | 11 | | | u | G. - - | *Grammoceras.* |
| — *multicostata*, Sow., see A. bisulcatus. | | | | | | | | | | | | | | | | | |
| — nitescens, Y. & B. - | | | | | 4 | | 6 | 7 | | | | | 1 | m | | S. G. O. Y. - | *A. algovianus*, Oppel. *Harpoceras.* |
| — nodotianus, d'Orb. - | | | | | 4 | | | | | | | | 1 | | | D. to Y. - | *Arietites.* |
| — normanianus, d'Orb. - | | | | | | 5 | 6 | | | | | | 1 | m | | Le. - - | *Harpoceras.* |
| — obesulus, Blake - | | | 2 | | | | | | | | | | 1 | | | Le. Y. - | *Arietites.* |
| — obtusus, Sow. - - | | | | 3 | | | | | | | | | 1 | | | D. to Y. - | Includes *A. Smithi*, Sow., *Arietites.* |
| — occidentalis, Haug. - | | | | | | | | | | | | 11 | | | u | G. - - | *Haugia.* |
| — ophioides, d'Orb. - | | | | | 4 | | | | | | | | 1 | | | Le. Y. | |
| — Oppeli, Schloen. - | | | | 3 | 4 | | | | | | | | 1 | | | S. Wk. Y. - | *Amaltheus.* |

| Species. | Rhætic Beds. | Lower. Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Middle. Am. margaritatus. | Am. spinatus. | Upper. Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mollusca—*cont.* | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
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| Ammonites Orbignyi, S. Buckm. | | | | | | | | | | | | 11 | | | u | × G. Y. - | *Grammoceras.* |
| — ovatus, Phil., see A. cæcilia. | | | | | | | | | | | | | | | | | |
| — oxynotus, Quenst. - | | | | 3 | 4 | | | | | | | | 1 | | | D. to Y. - | *Amaltheus.* *Oxynoticeras.* |
| — pettos, Quenst. - | | | | | 4 | | | | | | | | 1 | | | D. to Y. - | *A. Grenouillou*x d'Orb. *Ægoceras.* |
| — planicosta, Sow. - | | | 2 | 3 | 4 | | | | | | | | 1 | | | D. to Y. - | *Ægoceras.* *A. Dudressi*‹ d'Orb. *A. ziphus*, Ziet |
| — planorbis, Sow. - | | 1 | | | | | | | | | | | 1 | | | D. to Y. - | *Ægoceras*, *Psiloc* |
| — primordialis, Schloth. | | | | | | | | 7 | | 9 | 10 | | | m | u | O. to Y. - | *A. ovatus*, Y. & ] *Harpoceras.* |
| — priscus, S. Buckm. - | | | | | | | | | | | | 11 | | | u | × S. - | *Dumortieria.* |
| — pseudoradiosa, Branco | | | | | | | | | | | | 11 | | | u | × D. G. - | *Dumortieria.* |
| — quadratus, Haug. - | | | | | | | | | | | | 11 | | | u | G. - - | *Grammoceras.* |
| — radians, Rein - - | | | | | | | | | | | 10 | 11 | | | u | D. to R. - | *Harpoceras.* *Grammoceras.* *Dumortieria.* |
| — radiosus, Seeb. - | | | | | | | | | | | | 11 | | | u | × G. - | *Dumortieria.* |
| — *raquinianus*, d'Orb., see A. crassus. | | | | | | | | | | | | | | | | | |
| — raricostatus, Ziet. - | | | 2 | 3 | 4 | | | | | | | | 1 | | | D. to Y. - | *Arietites.* |
| — rotiformis, Sow. - | | | 2 | 3 | | | | | | | | | 1 | | | D. S. Gl. Y.? | *A. obliquecostat* Ziet. *Arietites.* |
| — Sæmanni, Dum. - | | | | | | | | | | | | 11 | | | u | G. - - | *Grammoceras.* |
| — sagittarius, Blake - | | | | 3 | | | | | | | | | 1 | | | Wo. Y. - | *Ægoceras.* |
| — salisburgensis, von Hauer. | | | | 3 | | | | | | | | | 1 | | | Wo. - - | *Phylloceras.* |
| — sauzeanus, d'Orb. - | | | 2 | 3 | | | | | | | | | 1 | | | D. to Y. - | *Arietites.* |
| — scipionianus, d'Orb. - | | | 2 | | 4 | | | | | | | | 1 | | | S. G. Le. Y. | *Arietites.* |
| — semicelatus, Simps. - | | | | | | | | 7 | 8 | 9 | 10 | | | m | u | Nn. to Y. . | *Stephanoceras.* |
| — semicostatus, Y. & B. | | | 2 | 3 | 4 | | | | | | | | 1 | | | D. to Y. - | *A. geometricus*, C *Arietites.* |
| — serpentinus, Rein. - | | | | | | | | 7 | 8 | 9 | 10 | | | m | u | D. to Y. - | *Harpoceras.* |
| — serrodens, Quenst. - | | | | | | | | | | | | 11 | | | u | G. - | *Pelecoceras.* *Hudlestonia.* |
| — Simpsoni, Bean - | | | | 3 | | | | | | | | | | | | S. Wo. Y. - | *Amaltheus.* |
| — Slatteri, Wright - | | | | 3 | | | | | | | | | 1 | | | Wo. - - | *Ægoceras.* |
| — *Smithi*, Sow. = young of A. obtusus. | | | | | | | | | | | | | | | | | |
| — spinatus, Brug. - | | | | | | | | 7 | | | | | | m | | D. t o Y. - | *Amaltheus.* |
| — stellaris, Sow. - - | | | 2 | 3 | | | | | | | | | 1 | | | D. G. Li. Y. | *Arietites.* |

| Species. | Rhaetic Beds. | Lower. Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Middle. Am. margaritatus. | Am. spinatus. | Upper. Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MOLLUSCA—*cont.* | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| *Cephalopoda*—cont. | | | | | | | | | | | | | | | | | |
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| —— striatulus, Sow. - | | | | | | | | | 8 | | 10 | 11 | | m | u | D. S. G. Y. - | *Harpoceras. Grammoceras.* |
| —— striatus, Rein. - - | | | | | 4 | 5 | 6 | | | | | | l | | | D. to Y. - | *Ægoceras.* |
| —— subarmatus, Y. & B. - | | | | | | | | | 8 | | 10 | | | m | u | Nn. Y. - | *Stephanoceras.* |
| —— subcarinatus, Y. & B. | | | | | | | | | | 9 | 10 | | | | u | S. to Y. - | *Phylloceras.* |
| —— subconcavus, Y. & B. - | | | | | | | | | | | 10 | 11 | | | u | G. Y. - | *A. boulbiensis,* Y. & B. *Harpoceras,* |
| —— sublineatus, Oppel. - | | | | | | | | | | | | 11 | | | u | G. - - | *Lytoceras.* |
| —— submuticus, Oppel. - | | | | | 4 | | | | | | | | l | | | D. - - | *Ægoceras.* |
| —— subplanatus, Oppel. - | | | | | | | | | | 9 | 10 | 11 | | | u | D. Nn. Li. - | *A. complanatus,* d'Orb. |
| —— subplanicosta, Oppel. | | | | | 4 | 5 | | | | | | | l | | | D. G. Wk. Li. | *A. carusensis,* Wr. non d'Orb. *Ægoceras.* |
| —— subquadratus, S. Buckm. | | | | | | | | | | | | 11 | | | u | × G. - | *Grammoceras.* |
| —— Taylori, Sow. - | | | | 3 | 4 | | | | | | | | l | | | S. to Y. - | *Ægoceras.* |
| —— toarcensis, d'Orb. - | | | | | | | | | | | | 1 | | | u | × D. S. G. Y. | *A. thouarsensis. Grammoceras.* |
| —— *torus,* d'Orb., see A. Johnstoni. | | | | | | | | | | | | | | | | | |
| —— trivialis, Simps. - | | | | 3 | 4 | | | | | | | | l | | | D. to Y. - | *A. polymorphus,* Quenst. *Ægoceras, Amaltheus.* |
| —— Turneri, Sow. - - | | | 2 | | | | | | | | | | l | | | D. S. G. Gl. Y. | *Arietites.* |
| —— Valdani, d'Orb. - | | | | | 4 | | | | | | | | l | | | D. to Y. - | *Ægoceras.* |
| —— variabilis, d'Orb. - | | | | | | | | | | | 10 | 11 | | | u | D. G. O. Y. | *Harpoceras, Haugia.* |
| —— Wiltshirei, Wright - | | | | | | 5 | | | | | | | l | | | D. - - | *Amaltheus.* |
| —— Wrighti, S. Buckm. - | | | | | | | | | | | | 11 | | | u | × D. G. - | *Lytoceras,* near to *A. jurensis.* |
| —— zetes, d'Orb. - - | | | | | | | | 7 | | | | | | m | | S. G. - | *Phylloceras.* |
| —— *ziphus,* Ziet., see A. planicosta. | | | | | | | | | | | | | | | | | |
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| | | Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Am. margaritatus. | Am. spinatus. | Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | | | | | |
| Mollusca—cont. | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| *Cephalopoda*—cont. | | | | | | | | | | | | | | | | | |
| Ancyloceras - - - | | | | | | | | 7 | | | | | | m | | D. | |
| Belemnites abbreviatus, Sow. | | | | | | | | | | | | 11 | | | u | × D. | |
| — acutus, Mill. - - | | | 2 | 3 | 4 | | | | | | 10 | | l | | u | D. to Y. | |
| — apicicurvatus, Blainv. | | | | | 4 | 5 | 6 | 7 | | | 10 | | l | m | u | D. to Y. | |
| — araris, Dum. - - | | | | | 4 | | | | | | | | l | | | Wk. Y. | |
| — athleticus, Simps. - | | | | | | | | | | | | 11 | | | u | Nn. Y. | |
| — breviformis, Voltz - | | | | | 4 | 5 | 6 | 7 | 8 | 9 | | 11 | l | m | u | × D. to Y. | |
| — bruguierianus, d'Orb. | | | | 3 | | | | | | | | | l | | | D. | |
| — Bucklandi, Phil. - | | | | | 4 | 5 | | | | | | | l | | | D. Wk. | |
| — calcar, Phil. - - | | | 2 | 3 | 4 | | | | | | | | l | | | D. S. Wk. Y. | |
| — charmouthensis, Mayer | | | | | 4 | | | | | | | | l | | | D. Wk. Y. | |
| — clavatus, Blainv. - | | | | 3 | 4 | 5 | 6 | 7 | | | | | l | m | u | D. to Y. - | *B. pistilliformis*, Sow. |
| — clavellatus, Bean - | | | | | | | | 7 | | | | | | m | | Le. | |
| — compressus, Stahl. - | | | | | 4 | 5 | | 7 | | 9 | 10 | | l | m | | × D. G. S. Wk. Y. | *B. fournelianus*, d'Orb. |
| — crossotelus, Blake - | | | | | | | | | | 9 | | 11 | | | u | Nn. Y. | |
| — cylindricus, Simps. - | | | | | 4 | | 6 | 7 | 8 | | | | l | m | u | × O. Wk. Nn. Y. | |
| — elegans, Simps. - | | | | 3 | 4 | | | | | | | | l | m | | Wk. Le. Y. | |
| — elongatus, Sow. - | | | | 3 | 4 | 5 | 6 | 7 | | | 10 | | l | m | u | D. to Y. | |
| — excavatus, Phil. - | | | | | | | | | | | | | l | | | D. | |
| — grandævus, Phil. - | | | 2 | | | | | | | | | | l | | | S. | |
| — ilminsterensis, Phil. - | | | | | | | | | 8 | 9 | 10 | | | | u | S. G. O. Nn. | |
| — inæquistriatus, Simps. | | | | | | | | | | 9 | | | | | u | O. Y. | |
| — infundibulum, Phil. - | | | 2 | 3 | | | | | | | | | l | | | D. S. Le. Y. | |
| — insculptus, Phil. - | | | | | | | | | | | | | l | | | D. | |
| — irregularis, Schloth. - | | | | | | | | | | | | 11 | | | | × S. G. Nn. | |
| — junceus, Phil. - - | | | | | 4 | 5 | | | | | | | l | | | D. | |
| — lævis, Simps. - - | | | | | 4 | | | | | | | | l | | | Wk. Y. | |
| — levidensis, Simps. - | | | | | | | | | | | 10 | | | | u | Nn. Li. Y. | |
| — longissimus, Mill. - | | | | | 4 | 5 | | | | | | | l | | | D. Wk. | |
| — microstylus, Phil. - | | | | | 4 | | | 7 | | 9 | | | l | m | u | D. G. Y. | |
| — Milleri, Phil. - - | | | | 3 | 4 | 5 | 6 | 7 | | | | | l | m | | D. to Y. | |
| — minutus, Phil. - - | | | | | | | | | | | | | | | u | S. O. | |
| — nitidus, Phil. - - | | | | | 4 | 5 | | | | | | | l | | | D. Wk. O. | |
| — oxyconus, Quenst. - | | | | | 4 | | | | | | | | l | | | G. | |

| Species. | Rhætic Beds. | Lower. | | | | | Middle. | | Upper. | | | | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Am. margaritatus. | Am. spinatus. | Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | | | | | |
| **Mollusca**—*cont.* | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| *Cephalopoda*—cont. | | | | | | | | | | | | | | | | | |
| Belemnites palliatus, Dum. | | | | 3 | 4 | | | | | | | | 1 | | | Wk. Y. | |
| —— paxillosus, Schloth. - | | | | | 4 | 5 | 6 | 7 | | | | | 1 | m | | D. to Y. | |
| —— penicillatus, Sow. - | | | 2 | 3 | 4 | 5 | | | | | | | 1 | | | D. to Y. | |
| —— pollex, Simps. - - | | | | | 4 | | | | | | 10 | 11 | 1 | | u | D. to Y. | |
| —— quadricanaliculatus, Quenst. | | | | | | | | | | 9 | 10 | | | | u | × S. O. Nn. | |
| —— regularis, Phil. - | | | | | | | | | | 9 | | | | | u | O. Nn. | |
| —— striolatus, Phil. - | | | | | 4 | 5 | | | 8 | 9 | | | 1 | | u | D. O. Nn. Y. | |
| —— subaduncatus, Voltz - | | | | | | | | | 8 | 9 | | | | | u | O. Nn. Y. | |
| —— subtenuis, Simps. - | | | | | | | | | | 9 | 10 | 11 | | | u | G. to Y. | |
| —— tripartitus, Schloth. - | | | | | | | | | 8 | 9 | 10 | | | | u | S. to Y. | |
| —— tubularis, Y. & B. - | | | | | 4 | | | 7 | | 9 | | | | | u | × D. G. Li. Y. | *B. acuarius*, Schloth |
| —— umbilicatus, Mill. - | | | | | 4 | | | | | | | | 1 | | | G. | |
| —— unisulcatus, Blainv. - | | | | | | | | | | | | | | | u | O. | |
| —— ventralis, Phil. - | | | | | | | | | | 9 | | 11 | | | u | O. N. Y. | |
| —— virgatus, Mayer - | | | | | 4 | | 6 | | | | | | 1 | m | | Wk. Y. | |
| —— Voltzi, Phil. - - | | | | | | | | | | 9 | 10 | 11 | | | u | G. to Y. | |
| —— vulgaris, Y. & B. - | | | | | | 5 | 6 | 7 | | 9 | 10 | 11 | 1 | m | u | D. O. Nn. L. Y. | |
| Belemnosepia - - | | | | | | | | | | 9 | | | | | u | G. | |
| Geoteuthis bollensis, Schubl. | | | | | | | | | | | | | 1 | | | D. | |
| Nautilus astacoides, Y. & B. | | | | | | | | | | 9 | 10 | 11 | | | u | G. O. N. Y. | |
| —— intermedius, Sow. - | | | | 3 | 4 | | | | | | | | 1 | | | D. S. Wk. Y. | |
| —— Jourdani, Dum. - | | | | | | | | | | 9 | | | | | u | D. O. Nn. | |
| —— jurensis, Quenst. - | | | | | | | | | | | | 11 | | | u | Nn. Y. | |
| —— latidorsatus, d'Orb. - | | | | | | | | | | 9 | | | | | u | × G. Li. - | *N. toarcensis*, d'Orb |
| —— semistriatus, d'Orb. - | | | | | 4 | 5 | | 7 | | | | | 1 | m | u | D. S. G. Li. | |
| —— simillimus, Foord & Crick. | | | | | | | | | | | | | 1 | | | D. | |
| —— striatus, Sow. - - | | 1 | 2 | 3 | | 5 | | 7 | | | | 11 | 1 | m | u | × D. to Y. | |
| —— terebratus, Dum - | | | | | | | | | | 9 | | | | | u | Li. | |
| —— truncatus, Sow. - | | | 2 | | | | | 7 | | | | | 1 | m | | × G. Le. | |
| Onychites - - - | | | 2 | | | | | 7 | | | | | 1 | m | | S. Le. - | Hooklets of Cepha- pods. |
| Rhyncholites acutus, Münst. | | | | | 4 | | | | | | | | 1 | | | D. - - | Mandibles of *Nautil* |
| Rhynchoteuthis - - | | | | | | | | | | | | | m | | | D. | |
| Teudopsis - - - | | | | | | | | | 8 | | | | | | u | S. Y. | |

| Species. | Rhætic Beds. | Lower. Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Middle. Am. margaritatus. | Am. spinatus. | Upper. Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MOLLUSCA—*cont.* | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| *Cephalopoda*—cont. | | | | | | | | | | | | | | | | | |
| Xiphoteuthis elongata, De la Beche. | | | | | 4 | | | | | | | | 1 | | | D. - - | *X. Bechei*, Huxley, MS. (Day). |
| *Gasteropoda.* | | | | | | | | | | | | | | | | | |
| Actæon ? angulifer, Mart. - | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— fragilis, Dunk. - - | | 1 | 2 | 3 | | | | 7 | | | | | 1 | m | | Wo. Le. Y. | *Cylindrites.* |
| —— inermis, Terq. - | | | 2 | | | | | | | | | | 1 | | | Li. - - | *Tornatella.* |
| Actæonina avena, Terq. - | | | 2 | | | | | | | | | | 1 | | | Gl. - - | *Orthostoma.* |
| —— canariensis, Tate - | | | 2 | | 4 | | | | | | | | 1 | | | Gl. G. | |
| —— decorata, Mart. - | | | | | | | | | | | 10 | | | | u | Nn. | |
| —— Dewalquei, Oppel - | | | | | | 5 | | | | | | | 1 | | | G. | |
| —— Dumortieri, H. & W. - | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— ferrea, Wils. - - | | | | | | | | 7 | | | | | | m | | Le. | |
| —— frumentum, Terq. - | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— ilminsterensis, Moore | | | | | 4 | 5 | 6 | 7 | 8 | | | | 1 | m | u | S. to Y. - | *Actæon tesselatus*, Tate. |
| —— marginata, Simps. - | | | | | 4 | 5 | | | | 9 | 10 | | 1 | | u | S. G. Wk. Nn. Y. | *Tornatella capricorni*, Tate. |
| —— numismalis, Quenst. - | | | | | 4 | | | | | | | | 1 | | | Wk. | |
| —— sinemuriensis, Mart. - | | | 2 | | | | | 7 | | | | | 1 | m | | S. Le. Y. | |
| Alaria angulata, Moore - | | | | | | | | | | 9 | | | | | u | S. O. | |
| —— Hudlestoni, Wils. - | | | 2 | | | | | | | | | | 1 | | | G. | |
| —— semicostulata, Piette - | | | | | | | | | 8 | 9 | | | | | u | Nn. | |
| —— unispinosa, Moore - | | | | | | | | | 8 | 9 | 10 | | | | u | S. G. O. Nn. | |
| Amberleya Æmilius, d'Orb. | | | | | 4 | | | 7 | | | | | 1 | m | | S. Wk. - | *Eucyclus.* |
| —— acuminata, Chap. & D. | | | 2 | | 4 | | | | | | | | | | | D. S. Gl. Y. | |
| —— æolus, d'Orb. - - | | | | | | | | 7 | | | | | | m | | D. Nn. Le. - | ? = *Trochus. Æmilius*, d'Orb. |
| —— alpina, Stol. - - | | | | | | | | | | | | | | | | S. - | Fissure in Carboniferous Limestone. |
| —— ? apicalis, Moore - | | | 2 | | | | | | | | | | | | | Gl. | |
| —— Callipyge, Wilson - | | | | | | | 6 | | 8 | | | | | m | | Nn. | |
| —— capitanea, Goldf. - | | | | | | | | | | 9 | 10 | 11 | | | u | × S. G. O. Nn. | *Turbo Jonesi*, Moore. |
| —— Chapuisi, Terq. & P. - | | | 2 | | | | | | | | | | 1 | | | Wo. Li. Y. | *Trochus.* |
| —— conspersa, Tate - | | | | 3 | | | | 7 | 8 | | | | 1 | m | | Nn. Le. Y. - | *Eucyclus.* |
| —— Dunkeri, Goldf. - | | | | | | | | 7 | | | | | | m | | O. | |
| —— elegans, Münst. - | | | 2 | | 4 | | | | | | | | 1 | | | Le. Li. Y. | |
| —— gaudryana, d'Orb. - | | | 2 | 3 | 4 | 5 | | 7 | 8 | | | | 1 | m | u | D. to Y. - | *Turbo polita*, Moore. |
| —— grandis, Moore - | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— imbricata, Sow. - | | | 2 | 3 | 4 | 5 | 6 | 7 | | | | | 1 | m | | D. to Y. - | *Trochus, Tectaria.* |

| Species. | Rhætic Beds. | Lower. Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Middle. Am. margaritatus. | Am. spinatus. | Upper. Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mollusca—*cont.* | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| *Gasteropoda*—cont. | | | | | | | | | | | | | | | | | |
| Amberleya liassica, Mart. - | | | 2 | | | | | | | | | | l | | | S. Gl. | |
| —— Lycetti, Moore - | | | | | | | | | | | 10 | | | | u | S. | |
| —— Nireus, d'Orb. - - | | | | | | | | 7 | | | | | | m | | D. S. O. Nn. Y. | |
| —— selecta, Chap. & D. - | | | 2 | | 4 | | | | | | | | l | | | G. Y. | |
| —— turrita, Moore - - | | | 2 | | | | | | | | | | l | | | Gl. | |
| —— undulata, Phil. - | | | 2 | | | 5 | 6 | 7 | | | | | l | m | | Le. Y. | |
| Ataphrus linctus, Moore - | | | | | | | | 7 | 8 | | | | | m | u | S. O. Nn. - | *Turbo nudus*, Moo |
| Bourguetia globosa, d'Orb. | | | 2 | | | | | | | | | | l | | | Gl. | |
| —— liasina, Terq. - - | | | 2 | | | | | | | | | | l | | | Gl. | |
| —— turbinata, Stol. - | | | | | 4 | | | 7 | 8 | | 10 | | l | m | u | S. O. Le. Nn. Y. | *Trochus latilab* Stol., *Phasian* *Pseudomelania*. |
| Cerithinella confusum, Tate | | | | | | | | 7 | 8 | | | | | m | u | D. O. Nn. Le. | *Cerithium*. |
| Cerithium acuticostatum, Terq. | | | 2 | | | | | | | | | | l | | | G. Gl. | |
| —— armatum, Goldf. - | | | | | 4 | | | | | | 10 | 11 | l | | u | × G. to Y. | |
| —— asperulum, Moore - | | | | 3 | | | | 7 | 8 | | | | l | m | u | S. Le. O. Nn. | |
| —— Brodiei, Tate - - | | | | | 4 | | | | | | | | l | | | G. Wk. | |
| —— camertonense, Moore - | | | | | 4 | | | 7 | | | | | l | m | | S. G. Wk. Le. | |
| —— coronatum, Moore - | | | | | | | | 7 | 8 | 9 | | | | m | u | S. Nn. | |
| —— ? costellatum, Münst. - | | | | | | | | | | | 10 | | | | u | S. Nn. | |
| —— costulatum, Desl. - | | | | | | | | 7 | | | 10 | | | m | u | S. Le. to Li. | |
| —— Dayi, Tate - - | | | | | | | | 7 | | | | | | m | | D. | |
| —— Dumortieri, Mart. - | | | 2 | 3 | | | | | | | | | l | | | S. Gl. G. | Cerithinella. |
| —— ferreum, Tate - - | | | | | | | | 7 | 8 | | | | | m | u | O. Nn. Le. | |
| —— gradatum, Moore - | | | | | | | | 7 | 8 | | | | | m | u | S. Gl. O. Nn. | |
| —— gratum, Terq. - - | | | 2 | 3 | | | | | | | | | l | | | Gl. Y. | |
| —— Huttoni, Tate - - | | | | | | | | 7 | | | | | | m | | G. | |
| —— ? Ibex, Tate - - | | | | 3 | 4 | | | | | | | | l | | | G. Wk. Le. | |
| —— ilminsterense, Moore - | | | | | | | | 7 | 8 | | | | | m | u | S. Nn. Le. | |
| —— liassicum, Moore - | | | | 3 | | | | 7 | 8 | 9 | | | l | m | u | D. to Y. | |
| —— ligaturale, Tate - | | | 2 | | 4 | | | | | | | | l | m | | Le. Li. | |
| —— minor, Moore - | | | | | | | | | | | 10 | | | | u | S. | |
| —— nodulosum, Moore - | | | 2 | | | | | | | | | | l | | | S. Gl. | |
| —— paludinare, Terq. - | | | 2 | | | | | | | | | | l | | | S. Gl. | |
| —— pentacostæ, Moore - | | | 2 | | | | | | | | | | l | | | Gl. | |
| —— planicostatum, Moore | | | 2 | | | | | | | | | | l | | | Gl. | |

| Species. | Rhætic Beds. | Lower. Am. planorbis. | Lower. Am. Bucklandi. | Lower. Am. oxynotus. | Lower. Am. Jamesoni. | Lower. Am. capricornus. | Middle. Am. margaritatus. | Middle. Am. spinatus. | Upper. Am. annulatus. | Upper. Am. serpentinus. | Upper. Am. communis. | Upper. Am. jurensis. | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mollusca—*cont.* | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| *Gasteropoda*—cont. | | | | | | | | | | | | | | | | | |
| Cerithium ? planum, Moore | | | | | | | | | | | 10 | | | | u | S. | |
| —— porulosum, Terq. - | | | 2 | | | | | | | | | | l | | | Gl. | |
| —— pupa, Mart. - - | | | 2 | | | | | | | | | | l | | | Gl. | |
| —— ? pyramidale, Moore - | | | | | | | | 7 | 8 | | | | | m | u | S. O. Nn. | |
| —— quinetteum, Piette - | | | 2 | | | | | | | | | | l | | | G. Gl. | |
| —— raricostatum, Tate - | | | | 3 | | | | | | | | | l | | | D. G. | |
| —— reticulatum, Desl. - | | | | | | | | 7 | 8 | | | | | m | u | O. Nn. Le. | |
| —— Semele, d'Orb. - - | | | 2 | | | | | | | | | | l | | | S. Gl. Li. Y. | |
| —— Slatteri, Tate - - | | | | | 4 | | | | | | | | l | | | D. G. Wk. Y. | |
| —— spiratum, Moore - | | | 2 | | | | | | | | | | l | | | Gl. Y. | |
| —— subfistulosum, Tate - | | | 2 | | | | | | | | | | l | m | | Le. Li. | |
| —— subliassicum, H. & W. | | | | | | | | 7 | | | | | | m | | S. - - | *Nerinæa liassica*, Moore. |
| —— sublineatum, Moore - | | | | | | | | | | 9 | | | | | u | S. | |
| —— trinodulosum, Mart. - | | | 2 | | | | | | | | | | l | | | S. | |
| —— verrucosum, Terq. - | | | 2 | | | | | | | | | | l | | | S. Gl. | |
| —— see also Cryptaulax and Turritella. | | | | | | | | | | | | | | | | | |
| Chemnitzia abbreviata, Terq. | | | 2 | | | | | | | | | | l | | | S. Gl. - | *Melania.* |
| —— acuta, Moore - - | | | 2 | | | | | | | | | | l | | | Gl. | |
| —— Berthaudi, Dum. - | | | 2 | 3 | 4 | | | | | | | | l | | | S. G. Le. Y. | |
| —— Blainvillei, Münst. - | | | | 3 | 4 | | 6 | 7 | 8 | 9 | | | l | m | u | S. to Y. - | *Cerithium.* |
| —— carusensis d'Orb. - | | | | | 4 | 5 | | | | | | | l | | | D. S. G. Y. | |
| —— citharella, Tate - | | | | 3 | 4 | 5 | 6 | | | | | | l | m | | S. O. Le. Y. | |
| —— Collenoti, Terq. & Piette. | | | 2 | 3 | 4 | | | | | | | | l | | | Wo. Wk. Y. | Turritella **Dunkeri**, Terq. |
| —— complicata, Tate - | | | | | | | | 7 | | | | | | m | | S. | |
| —— corvaliana, d'Orb. - | | | | | | | 6 | | | | | | l | m | | D. | |
| —— crassicosta, Tate - | | | | | 4 | | | | | | | | l | | | Wk. Salop. | |
| —— dunravenensis, Moore | | | 2 | | | | | | | | | | l | | | S. Gl. | |
| —— foveolata, Tate - | | | | | 4 | | 6 | | 8 | | | | l | m | u | O. Wk. Nn. Y. | |
| —— ? liassica, Quenst. - | | | | | 4 | | | | | | | | l | | | S. G. Li. - | *Scalaria.* |
| —— ? periniana, d'Orb. - | | | | | 4 | 5 | | 7 | 8 | | | | l | m | u | D. Nn. Le. | |
| —— polita, Mart. - - | | | 2 | | | | | | | | | | l | | | S. Gl. | |
| —— semitecta, Tate - | | | | | 4 | | 6 | 7 | 8 | | | | l | m | u | S. Wk. Y. - | ? ***Cerithium sublineatum***, Moore. |
| —— transversa, Blake - | | | | | | | | | | | 10 | | | | u | Nn. Y. | |

| | | Lower. | | | | | Middle. | | Upper. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species. | Rhætic Beds. | Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Am. margaritatus. | Am. spinatus. | Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
| Mollusca—*cont.* | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| *Gasteropoda*—cont. | | | | | | | | | | | | | | | | | |
| Chemnitzia trivia, Tate - | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— undulata, Benz. - | | | | | 4 | | | 7 | 8 | | | | 1 | m | u | D. to Y. - | Turritella anon Moore. |
| —— unicingulata, Terq. - | | | | | | | | 7 | | | | | 1 | m | | S. Y. | |
| —— Youngi, Simps. - | | | | | 4 | | | | | | | | 1 | | | Wk. Y. | |
| —— see also Cerithium and Pseudomelania. | | | | | | | | | | | | | | | | | |
| Cirrus Leachi, Sow. - | | | | | | | | | | | 10 | | | | u | S. - - | *Turbo Hörnesi*, M non Stol. |
| Cryptænia affinis, Tate - | | | | | | | | | | | | | 1 | | | S. | |
| —— Brycei, Tate - - | | | | | | | | | | | | | 1 | | | D. | |
| —— compressa, Sow. - | | | | | | | | 7 | | | | | | m | | G. | |
| —— consobrina, Tate - | | | | 3 | | | | 7 | 8 | | | | 1 | m | u | G. O. Le. Nn. Li. Y. | |
| —— expansa, Sow. - - | | | 2 | 3 | 4 | 5 | 6 | 7 | | | | | 1 | m | | D. to Y. - | *Pleurotomaria, I cina.* |
| —— heliciformis, Desl. - | | | | | | | | 7 | 8 | | | | | m | u | S. O. N. Li. | *Pleurotomaria.* |
| —— rotellæformis, Dunk. - | | | 2 | 3 | | 5 | 6 | 7 | 8 | | | | 1 | m | u | D. to Y. - | *Pleurotomaria.* |
| —— solarioides, Sow. - | | | 2 | | | | | 7 | | | | | 1 | m | | S. Le. Y. | |
| Cryptaulax scobina, Desl. - | | | | | | | | | | | 10 | 11 | | | u | × D. S. N. - | *Cerithium varicos* Desl. |
| Cylindrites æqualis, Wils. - | | | | | | | | 7 | | | | | | m | | Le. | |
| —— Whitfieldi, Moore - | | | | | 4 | | | 7 | 8 | | | | 1 | m | u | S. Wk. Nn. | Actæonina. |
| —— see also Actæonina. | | | | | | | | | | | | | | | | | |
| Delphinula reflexilabrum, d'Orb. | | | | | | | | | | | | | | | | S. - - | Liassic vein. |
| Discohelix aratus, Tate - | | | | | 4 | | 6 | 7 | | | | | 1 | m | | D. G. Y. - | *Straparollus.* |
| —— bellulus, Tate - - | | | | | 4 | | 6 | | | | | | 1 | m | | D. Y. | |
| —— cornucopiæ, Moore - | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— Dunkeri, Moore - | | | | | | | | | | | 10 | | | | u | S. | |
| —— semiclausus, Tate - | | | 2 | | | | | | | | | | 1 | | | Gl. Y. | |
| —— sinister, d'Orb. - | | | | | | | | 7 | | | | | | m | | D. S. - | Straparollus. |
| —— striatus, Piette - | | | 2 | | | | | | | | | | | | | S. Y. - | Straparollus. |
| —— wrightianus, Tate - | | | | | 4 | | | | | | | | 1 | | | D. | |
| *Emarginula*, see Rimula. | | | | | | | | | | | | | | | | | |
| *Eucyclus*, see Amberleya. | | | | | | | | | | | | | | | | | |
| Euomphalus ? minutus, Schübl. | | | | | | | | | 8 | 9 | 10 | | | | u | G. Nn. Y. - | *Natica pilula*, Tat |
| Exelissa numismalis, Tate - | | | | | 4 | | | | | | | | 1 | | | G. - - | *Kilvertia.* |
| Fusus ? - - - | | | 2 | | | | | | | | | | 1 | | | Gl. | |

| Species. | Rhætic Beds. | Lower. | | | | | Middle. | | Upper. | | | | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Am. margaritatus. | Am. spinatus. | Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | | | | | |
| [ollusca—*cont.* | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| *steropoda*—cont. | | | | | | | | | | | | | | | | | |
| *na*, see Cryptænia. | | | | | | | | | | | | | | | | | |
| na biornata, Tate | | | | | 4 | | | | 8 | | | | 1 | | u | D. O. Nn. | |
| rcularis, Moore | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| 'alis, Moore | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| miornata, Münst. | | | 2 | | | | ? | | | | | | 1 | | | S. Gl. Li. Y. | L.? clathrata, Desh. |
| da Cricki, Hudl. | | | | | | | | | | | 10 | | | | u | Nn. | |
| *ia*, see Chemnitzia Turritella. | | | | | | | | | | | | | | | | | |
| lonta humilis, Wils. | | | | 3 | | | | | | | 10 | | 1 | | u | Le. Li. | *Turbo.* |
| ndecolina, Wils. | | | | | | | | | | 9 | | | | | u | Li. | Ataphrus. |
| odesta, Tate | | | | | | | 7 | | | | | | | m | | G. | |
| Pelops, d'Orb. | | | | | | | | | | 9 | | | | | u | O. | |
| *ea*, see Cerithium. | | | | | | | | | | | | | | | | | |
| na arenacea, Terq. | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| nabis, Terq. | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| ettangiensis, Terq. | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| psis cancellata, re. | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| tigua, Terq. | | 1 | 2 | | | | | | | | | | 1 | | | S. Gl. | |
| evis, Stol. | | | | | | | | | | | | | | | | S. | Fissure in Carboniferous Limestone. |
| ansversa, Moore | | | | | | | | | | 9 | 10 | | | | u | S. O. Nn. | |
| pekei, Moore | | | | | | | | | | | 10 | | | | u | S. | |
| e also Peltarion. | | | | | | | | | | | | | | | | | |
| nia patroclus, Wilson | | | | | | | | | | 9 | | | | | u | R. | *Purpurina.* |
| us heliacus, d'Orb. | | | | | | | | | | | 10 | | | m | u | S. O. Nn. | *O. spinosus*, Moore. |
| *stoma*, see Actæonina. | | | | | | | | | | | | | | | | | |
| niso, see Trochus. | | | | | | | | | | | | | | | | | |
| a Beesleyi, Tate | | | | | | 5 | | | | | | | 1 | | | O. | |
| 'unkeri, Terq. | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| ratans, Tate | | | | | | | | 7 | | | | | | m | | G. | |
| ettangiensis, Terq. | | | 2 | | | | | | | | | | 1 | | | Gl. | *P. suttonensis*, Tawn. |
| Illigani, Tate | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| rnata, Moore | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| abrina, Tate | | | | | | | | | | | | | 1 | | | G. | |
| chmidti, Dunk. | | | 2 | | | | | | | | | | 1 | | | G. Gl. | |
| 'ion unilobatum, Desl. | | | | | | | | | | 9 | | | | | u | Nn. | Operculum of *Neritopsis.* |

| Species. | Rhætic Beds. | Lower. Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Middle. Am. margaritatus. | Am. spinatus. | Upper. Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| MOLLUSCA—*cont.* | | | | | | | | | | | | | | | | | |
| *Gasteropoda*—cont. | | | | | | | | | | | | | | | | | |
| Phasianella morencyana, Piette. | | | 2 | | | | | | | | | | l | | | S. Gl. Li. Y. | Bourguetia. |
| —— nana, Terq. | | | 2 | | | | | | | | | | l | | | D. Gl. Y. | |
| Pitonnillus conicus, d'Orb. | | | 2 | | 4 | | | 7 | | | | | l | m | | D. S. Wk. Nn. | *Rotella.* |
| —— linctus, Moore | | | | | 4 | | | 7 | 8 | | | | l | m | u | S. Wk. O. Nn. | |
| Pleuratella prima, Moore | | | 2 | | | | | | | | | | l | | | Gl. | |
| Pleurotomaria anglica, Sow. | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | | | | l | m | u | D. to Y. | = *Trochus* si Sow. *P. similis*, of authors. |
| —— araneosa, Desl. | | | | | | | | 7 | | | | | | m | | D. | |
| —— basilica, Ch. & D. | | | 2 | | | | | | | | | | l | | | Li. Y. | |
| —— bitorquata, Desl. | | | | | | | | 7 | | | | | | m | | D. | |
| —— canalis, Münst. | | | | | | | | 7 | | | | | | m | | Nn. Y. | |
| —— comptonensis, Moore | | | | | | | | | | | 10 | | | | u | S. | |
| —— fasciata, Sow. | | | | | | | | 7 | | | | | | m | | D. | |
| —— foveolata, Desl. | | | | | | | | 7 | | | | | l | m | | D. Nn. Y. | Var. *subturrita.* |
| —— gaudryana, d'Orb. | | | 2 | | | | | 7 | | | | | l | m | | D. S. | |
| —— gigas, Desl. | | | | | | | | 7 | | | | | | m | | S. | |
| —— granosa, Schloth. | | | | | 4 | | | | | | | | l | | | S. | *Trochus.* |
| —— helicinoides, Roem. | | | | | | | | 7 | 8 | | | | | m | u | S. to Y. | *Trochus carina* Moore. |
| —— Hennocqui, Terq. | | | 2 | | | | | | | | | | l | | | S. Y. | |
| —— isarensis, d'Orb. | | | | | | | | | | | 10 | | | | u | S. | |
| —— midas, d'Orb. | | | | | | | | | | 9 | | | | | u | S. | |
| —— mendipensis, Moore | | | | | | | | | | | | | | | | S. | Fissure in Ca ferous Limesto |
| —— mirabilis, Desl. | | | | | | | | 7 | | | | | | m | | D. O. Nn. | |
| —— Mopsa, d'Orb. | | | | | | | | | | | | | | | | S. | Fissure. |
| —— mosellana, Terq. | | | 2 | | | | | | | | | | l | | | G. Li. | |
| —— nucleus, Terq. | | | 2 | | | | | | | | | | l | | | Gl. | |
| —— pinguis, d'Orb. | | | | | | | | 7 | | | | | | m | | D. | *P. foveolata* var *guis*, Desl. |
| —— precatoria, Desl. | | | 2 | | | | | 7 | | | | | l | m | | D. Le. | |
| —— procera, d'Orb. | | | | | 4 | | | 7 | | | | | l | m | | D. Wk. Y. | |
| —— psilonoti, Quenst. | | | 2 | | | | | | | | | | l | | | Wk. Li. | |
| —— raricostati, Tate | | | | 3 | | | | | | | | | l | | | G. | |
| —— rustica, Desl. | | | 2 | | | | | 7 | 8 | | | | l | m | u | D. to Y. | |
| —— sabrina, Tate | | | | | | | | 7 | | | | | | m | | G. | |

| Species. | Rhætic Beds. | Lower. | | | | | Middle. | | Upper. | | | | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Am. margaritatus. | Am. spinatus. | Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | | | | | |
| Mollusca—*cont.* | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| *Gasteropoda*—cont. | | | | | | | | | | | | | | | | | |
| Pleurotomaria subtilis, Münst. | | | | | | | | | | 9 | | | | | u | Li. | |
| —— sulcosa, Desl. - - | | | | | | | | 7 | | | | | | m | | D. S. - | |
| —— subturrita, d'Orb. - | | | 2 | | | | | | | | | | l | | | Li. Y. | *P. tectaria*, Tate. |
| —— Theresa, Dum. - - | | | | | | | | | 8 | 9 | | | | | u | O. Nn. | |
| —— trocheata, Terq. - | | | 2 | | | | | | | | | | l | | | S. | |
| —— see also Cryptænia and Turbo. | | | | | | | | | | | | | | | | | |
| Pseudomelania brannoviensis, Dum. | | | | | | | | 7 | | | | | | m | | Le. - - | *Chemnitzia.* |
| Pterocheilos primus, Moore | | | 2 | | | | | | | | | | l | | | Gl. | |
| Purpurina armata, Tate - | | | | | | | | | | 9 | | | | | u | O. | |
| —— ornatissima, Moore - | | | | | | | | 7 | | | 10 | | | m | u | S. Nn. | |
| —— see also Nortonia. | | | | | | | | | | | | | | | | | |
| Rimula elegans, Moore - | | | 2 | | | | | | | | | | l | | | Gl. | |
| —— liasina, Terq. - - - | | | 2 | | | | | | | | | | l | | | Gl. | |
| —— punctata, Moore - | | | | | | | | | | | 10 | | | | u | S. | |
| *Rotella*, see Pitonnillus and Cryptænia. | | | | | | | | | | | | | | | | | |
| *Scalaria*, see Chemnitzia. | | | | | | | | | | | | | | | | | |
| Solarium crenulatum, Moore. | | | | | | | | 7 | | | | | | m | | S. | |
| —— inornatum, Tate - | | | | | | | 6 | | | | | | | m | | G. | |
| —— lenticulare, Terq. - | | | 2 | | | | | | | | | | l | | | S. | |
| —— lucens, Tate - - | | | | | | 5 | 6 | | | | | | l | m | | G. | |
| —— lunatum, Moore - | | | | | | | | | | | | | | | | S. - - | Fissure in Carboniferous Limestone. |
| *Straparollus*, see Discohelix. | | | | | | | | | | | | | | | | | |
| Tornatella Buvignieri, Terq. | | | | | 4 | | | | | | | | l | | | S. - - | Actæon. |
| —— secale, Terq. - - | | | 2 | | | | | | | | | | | | | Gl. - - | Actæon. |
| Trochotoma brocastellensis, Moore. | | | 2 | | | | | | | | | | l | | | Gl. | |
| —— Lycetti, Moore - | | | 2 | | | | | | | | | | l | | | Gl. | |
| Trochus actæon, d'Orb. - | | | | | 4 | | | | | | | | l | | | D. | |
| —— acutus, Schloth. - | | | | | 4 | 5 | | | | | | | l | | | D. S. | |
| —— ægion, d'Orb. - - | | | | | 4 | | | 7 | | | | | l | m | u | D. S. O. Nn. Le. | |
| —— Andersoni, Tate - | | | 2 | | | | | | | | | | l | | | Gl. | |
| —— apicalis, Moore - | | | 2 | | | | | | | | | | l | | | Gl. | |

| SPECIES. | Rhætic Beds. | Lower. Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Middle. Am. margaritatus. | Am. spinatus. | Upper. Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | Lower Lias. | Middle Lias. | Upper Lias. | LOCALITIES. | REMARKS. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MOLLUSCA—*cont.* | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| *Gasteropoda*—cont. | | | | | | | | | | | | | | | | | |
| Trochus ariel, Dum. | | | | | | | | 7 | 8 | | | | | m | u | Nn. Le. | |
| — avernus, Stol. | | | | | 4 | | | 7 | | | | | 1 | m | | S. | |
| — concinnus, Moore | | | | | 4 | | | | | | | | 1 | | | S. | |
| — Cricki, Wilson | | | | | | | 6 | | | | | | | m | | Nn. | |
| — dalbiensis, Wilson | | | | 3 | | | | | | | | | 1 | | | Le. | |
| — Deslongchampsi, Moore. | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| — duplicatus, Sow. | | | | | | | | | | | 10 | | | | u | × Nn. | |
| — Elizæ, Moore | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| — epulus, d'Orb. | | | | | | | | 7 | | | | | | m | | D. S. | |
| — fidia, d'Orb. | | | | | | | | 7 | | | | | | m | | Le. | Amberleya. |
| — flexicostatus, Moore | | | | | 4 | | | 7 | 8 | | | | 1 | m | u | S. Nn. Wk. | |
| — ? gradatus, Moore | | | | | | | | | | | | | | | | S. | Fissure in Ca… ferous Limesto… |
| — holwellensis, Moore | | | | | | | | | | | | | | | | S. | Fissure in Ca… ferous Limesto… |
| — inconstans, Tate | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| — ? langanensis, Moore | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| — limbatus, Schloth. | | | | | 4 | | | | | | | | 1 | | | S. Wk. | Palæoniso. |
| — lineatus, Moore | | | | | | | | 7 | | | | | | m | | D. S. Le. | |
| — mammillaris, Moore | | | | | 4 | | | 7 | | | | | 1 | m | | S. | |
| — Mariæ, d'Orb. | | | | | | | | 7 | | | | | | m | | D. | Palæoniso. |
| — monoplicus, d'Orb. | | | | | | | | 7 | | | | | | m | | D. | |
| — niortensis, d'Orb. | | | | | | | | 7 | | | | | | m | | × D. Nn. | |
| — nodulatus, Moore | | | | | | | | 7 | | | | | | m | | S. Nn. | |
| — northamptonensis, Wilson. | | | | | | | | | | | 10 | | | | u | Nn. | |
| — Pandion, Dum. | | | | | 4 | | | | 8 | | | | 1 | | u | O. Wk. Nn. | |
| — pethertonensis, Moore | | | | | | | | 7 | 8 | | | | | m | u | S. Nn. Le. | |
| — Pluto, Dum. | | | | | 4 | | | 7 | | | | | 1 | | | Wk. Nn. | |
| — pyramidalis, Buckm. | | | | | | | | 7 | | | | | | m | | G. | |
| — redcarensis, Tate | | | 2 | | 4 | | | | | | | | 1 | | | S. Wk. Y. | |
| — rotulus, Stol. | | | | | | | | 7 | 8 | | | | | m | u | Nn. Le. | |
| — sagenatus, Wilson | | | | | | | | 7 | 8 | | | | | m | u | Nn. | |
| — similis, Moore | | | | | | | | 7 | | | 10 | | | m | u | S. Nn. | |
| — solitarius, Tate | | | | | 4 | | | | | | | | 1 | | | S. | |
| — Thetis, Münst. | | | | | 4 | | | 7 | 8 | | | | 1 | m | u | S. to Y. | *Turbo helicif…* Quenst. |

| Species. | Rhætic Beds. | Lower. Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Middle. Am. margaritatus. | Am. spinatus. | Upper. Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mollusca—*cont.* | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| *Gasteropoda*—cont. | | | | | | | | | | | | | | | | | |
| Trochus tiarellus, Tate | | | | | | | | 7 | | | | | | m | u | O. Li. | |
| — ? trimonilis, d'Orb. | | | | | | | | | | 9 | | | | | u | S. | |
| — see also Amberleya, Pleurotomaria, and Turbo. | | | | | | | | | | | | | | | | | |
| Turbo aciculus, Stol. | | | | | | | | 7 | | | | | | m | | Nn. Y. | |
| — admirandus, Tate | | | | 3 | 4 | | | | | | | | l | | | G. Wo. Wk. | |
| — bifurcatus, Moore | | | | | 4 | | | | | | | | l | | | S. | |
| — brocastellensis, Moore | | | 2 | | | | | | | | | | l | | | Gl. | |
| — bullatus, Moore | | | | | 4 | | | 7 | 8 | | | | l | m | u | S. O. Nn. Le. | Ataphrus. |
| — ? constrictus, Moore | | | | | | | | | | | 10 | | | | u | S. | |
| — crassistomus, Tate | | | | | 4 | | | | | | | | l | | | Wk. | |
| — cryptænioides, Tate | | | | | 4 | | | | | | | | l | | | G. | |
| — cyclostoma, Benz. | | | | | 4 | | 6 | 7 | 8 | | | | l | m | u | S. G. to Y. | |
| — elegantissimus, Moore | | | | | | | | 7 | | | | | | m | | S. | |
| — Itys, d'Orb. | | | | | | | | 7 | | | | | | m | | D. | |
| — leo, d'Orb. | | | | | 4 | | | 7 | | | | | l | m | | S. | |
| — latilabrus, Stol. | | | | | | | | 7 | | | | | | m | | D. Le. Y. | |
| — lineatus, Moore | | | | | 4 | | 6 | 7 | 8 | | | | | m | u | D. S. O. Nn. Y. | |
| — lucilius, Dum. | | | | | 4 | | | | 8 | | | | l | | u | O. Nn. Wk. | |
| — midas, d'Orb. | | | | | | | | 7 | | | | | | m | | D. | |
| — nodulo-carinatus, Moore. | | | | | | | | | | | | | | | | S. | Fissure in Carboniferous Limestone. |
| — Orion, d'Orb. | | | | | 4 | | | 7 | | | | | l | m | | S. G. | |
| — Philemon, d'Orb. | | | 2 | | | | | | | | | | l | | | Gl. | |
| — Piettei, Mart. | | | 2 | | | | | | | | | | l | | | Gl. | |
| — reticulatus, Moore | | | 2 | | | | | | | | | | l | | | Gl. Y. | |
| — rugiferus, Moore | | | | | | | | 7 | | | | | | m | | S. Le. | { *Pleurotomaria costulatum*, Moore. *T. coronatus*, Moore. |
| — Rutteri, Moore | | | | | | | | 7 | | | 10 | | | m | u | S. Nn. | |
| — socconensis, d'Orb. | | | | | 4 | | | | | | | | l | | | S. G. | { *Trochus pethertonensis*, Moore (Tate). |
| — solarium, Piette | | | 2 | 3 | | | | | | | | | l | | | Gl. Wo. Li. Y. | = *T. Burtoni*, Tate. |
| — ? solidus, Moore | | | | | | | | | | | | | | | | S. | Fissure in Carboniferous Limestone. |
| — subelegans, Münst. | | | 2 | | | | | | | | | | l | | | G. Gl. Li. | |
| — ? Theodori, Mart. | | | | | | | | | 8 | | | | | | u | Le. | |
| — ? tumidus, Moore | | | 2 | | | | | | | | | | l | | | S. Gl. | |

| Species. | Rhætic Beds. | Lower. Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Middle. Am. margaritatus. | Am. spinatus. | Upper. Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| MOLLUSCA—*cont.* | | | | | | | | | | | | | | | | | |
| *Gasteropoda*—cont. | | | | | | | | | | | | | | | | | |
| Turbo varians, Moore | | | | | | | | | 8 | | | | | | u | S. O. Nn. | |
| — Wilsoni, Tate | | | 2 | | | | | | | | | | 1 | | u | O. Y. | |
| — see also Amberleya, Cirrus, Monodonta, and Trochus. | | | | | | | | | | | | | | | | | |
| Turritella crassilabrata, Terq. | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| — Deshayesea, Terq. | | | 2 | | | | | | | | | | 1 | | | S. Gl. Li. Y. | |
| — Dunkeri, Terq. | | | 2 | 3 | 4 | | | | 8 | | | | 1 | | u | G. O. Wk. Nn. Li. Y. | |
| — Falsani, Dum. | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| — ? Howsei, Moore | | | | | | | | | | | | | | | | S. | Fissure in Carboniferous Limestone. |
| — Humberti, Mart. | | | 2 | | | | | | | | | | 1 | | | S. Gl. | |
| — Juliana, Dum. | | | | | | | | | 8 | | | | | | u | O. Nn. | |
| — semiornata, Terq. | | | 2 | | | | | 7 | | | | | 1 | m | | D. Li. | |
| — similis, Moore | | | | | | | | 7 | | | | | | m | | S. | |
| — tenuicostata, Portl. | | | 2 | | | | | | | | | | 1 | | | Gl. | Cerithium. |
| — tricincta, Goldf. | | | | | 4 | | | | | | | | 1 | | | S. Y. | |
| — trigemmatum, Wils. | | | | 3 | | | | | | | | | 1 | | | Le. | Cerithium. |
| — Zenkeni, Dunk. | | | 2 | 3 | | | | | | | | | 1 | | | S. G. Gl. Y. | |
| — see also Mathilda. | | | | | | | | | | | | | | | | | |
| *Scaphopoda.* | | | | | | | | | | | | | | | | | |
| Dentalium angulatum, Buckm. | | | | | 4 | | | | | | | | 1 | | | Wk. | |
| — elongatum, Münst. | | | | | 4 | | 6 | 7 | 8 | 9 | | 11 | 1 | m | u | S. G. Nn. Y. | *D. gracilis*, Moore; *D. compressum*, d'Orb.; *D. trigonalis*, Moore. |
| — etalense, Terq. and Piette. | | | 2 | | 4 | | | | | | | | 1 | | | G. Y. | *D. Portlocki*, Tate. |
| — giganteum, Phil. | | | | | | | 6 | 7 | | | | | | m | | S. G. Wk. Y. | |
| — liassicum, Moore | | | | | 4 | | | | 8 | 9 | 10 | | 1 | m | u | S. Nn. Y. | |
| — limatulum, Tate | | | 2 | | | | | | | | | | 1 | | | Salop. Y. | |
| — minimum, Strickl. | | | | | 4 | | | | | | | | 1 | m | | D. G. Wo. Wk. Li. | |
| — tenue, Portl. | | | 2 | | | | | | | | | | 1 | | | G. Gl. | |
| *Lamellibranchiata.* (*Pelecypoda.*) | | | | | | | | | | | | | | | | | |
| Anatina numismalis, Tate | | | | | 4 | | 6 | 7 | 8 | | | | 1 | m | u | G. Nn. Le. Y. | |

| Species. | Rhætic Beds. | Lower. | | | | | Middle. | | Upper. | | | | Lower Lias. | Middle Lias. | Upper Lias. | Localities | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Am. margaritatus. | Am. spinatus. | Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | | | | | |
| Mollusca—*cont.* | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| *Lamellibranchiata*—cont. | | | | | | | | | | | | | | | | | |
| **Anomia alpina, Winkl.** - | × | | 2 | 3 | | | | | | | | | 1 | | | Li. Y. - | *A. pellucida*, Ter |
| —— **numismalis, Quenst.** - | | | | | 4 | 5 | | | 8 | | | | 1 | | u | Wk. O. Nn. | |
| —— **striatula, Oppel** - | | 1 | 2 | | | | | | | | | | 1 | | | S. Y. | |
| —— **see also Ostrea.** | | | | | | | | | | | | | | | | | |
| **Arca elegans, Roem.** - | | | | | | | | | | | 10 | | | | u | O. N. - | *Cucullæa.* |
| —— **elongata, Buckm.** - | | 1 | | | 4 | 5 | | 7 | | | | | 1 | m | | S. G. | |
| —— **interrupta, Moore** - | | | | | | | | | 8 | | | | | | u | S. O. Nn. | |
| —— **liasina, Roem** - - | | | | | | | | 7 | | | | | | m | | Nn. | |
| —— **numismalis, Tate** - | | | | | 4 | | | | | | | | 1 | | | G. | |
| —— **Stricklandi, Tate** - | | | | | 4 | 5 | | 7 | | | | | 1 | m | | S. G. Wk. O. Nn. Li. | *A. truncata*, Bu |
| —— **see also Macrodon.** | | | | | | | | | | | | | | | | | |
| **Arcomya concinna, Tate** - | | | | | | | | 7 | | | | | | m | | O. Y. | |
| —— **elongata, Roem.** - | | | | | 4 | | 6 | 7 | | | | | 1 | m | u | G. to Y. | |
| —— **longa, Buv.** - - | | | | | | | | 7 | | | | | | m | | D. ?. Y. | |
| —— **vetusta, Phil.** - - | | | | 3 | 4 | | 6 | 7 | 8 | 9 | | | 1 | m | u | D. Nn. Le. Y. | *Sanguinolaria.* |
| **Astarte camertonensis, Moore.** | | | 2 | | 4 | | | | | | | | 1 | m | u | D. S. G. Wk. Li. | |
| —— **cingulata, Terq.** - | | | 2 | 3 | | | | | | | | | 1 | | | Gl. Wo. Y. | |
| —— **depressa, Goldf.** - | | | | | | | | | 8 | | | | | | u | Nn. O. | |
| —— **Duncani, Tawn.** - | | 1 | | | | | | | | | | | 1 | | | Gl. | |
| —— **duplicata, Moore** - | | | | | | | | 7 | | | | | | m | | S. | |
| —— **fontis, Dum.** - - | | | | | | | | | 8 | | | | | | u | O. Nn. | |
| —— **lurida, Sow.** - - | | | | | | | | | | 9 | | 11 | | | u | × G. Nn. | |
| —— **obsoleta, Dunk.** - | | 1 | 2 | 3 | 4 | 5 | | | | | | | 1 | ? | | S. G. Wk. O. Y. | { *A. consobrina*, & Dew. ?*A. dentilabrum* |
| —— **Oppeli, Moore** - - | | | 2 | | 4 | | | | | | | | 1 | | | S. Y. | |
| —— **parallela, Moore** - | | | | | | | | | | 9 | | | | | u | S. Nn. | |
| —— **rugata, Quenst.** - | | | | | | | | 7 | 8 | | | | | m | u | Nn. O. Y. - | *Isocardia.* |
| —— **striato-sulcata, Roem.** | | | | 3 | 4 | 5 | 6 | 7 | 8 | 9 | | | 1 | m | u | S. to Y. - | { *A. amalthei*, Qu *A. minima* of authors. |
| —— **subcarinata, Münst.** - | | | | | | | | | 8 | | | | | | u | Nn. | |
| —— **subtetragona, Goldf.** - | | | | | | | | | 8 | 9 | | | | | u | O. Nn. | |
| —— **Voltzi, Goldf.** - - | | | | | | | | | 8 | | 10 | | | | u | O. Nn. Li. | |
| —— **see also Cardita.** | | | | | | | | | | | | | | | | | |
| **Avicula Alfredi, Terq.** - | | | 2 | | | | | | | | | | 1 | | | Gl. | |

| | | Lower. | | | | | Middle. | | Upper. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SPECIES. | Rhætic Beds. | Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Am. margaritatus. | Am. spinatus. | Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | Lower Lias. | Middle Lias. | Upper Lias. | LOCALITIES. | REMARKS. |
| MOLLUSCA—*cont.* | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| *Lamellibranchiata*—cont. | | | | | | | | | | | | | | | | | |
| Avicula calva, Schloenb. - | | | 2 | | | 5 | 6 | 7 | 8 | | | | 1 | m | u | S. Wk. Y. | |
| — — cygnipes, Y. & B. - | | 1 | 2 | | 4 | | 6 | 7 | | | | | 1 | m | | S. to Y. - | *A. longicostata*, St |
| — — Dunkeri, Terq. - | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| — — imbricata, Moore - | | | | | | | | | | 9 | | | | | u | S. Nn. | |
| — — inæquivalvis, Sow. - | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 1 | m | u | × D. to Y. - | { *A. novemc* Brown. *A. sinemuri* d'Orb. |
| — — longiaxis, Buckm. - | | | | | 4 | 5 | | | | | | | 1 | | | G. | |
| — — nuda, Moore - - | | | | | | | | | | | | | | | | S. | Horizon doubtful. |
| — — papyria, Quenst. - | | 1 | 2 | | 4 | | 6 | 7 | 8 | | | | 1 | m | u | D. O. to Y. | |
| — — substriata, Zieten - | | | | | 4 | | 6 | 7 | | 9 | 10 | 11 | 1 | m | u | G. to Y. | |
| — — see also Monotis. | | | | | | | | | | | | | | | | | |
| Cardinia attenuata, Stutch. | | | 2 | 3 | 4 | 5 | | | | | | | 1 | | | S. G. Wk. O. Y. | |
| — — concinna, Stutch. - | | | 2 | | 4 | | | 7 | 8 | | | | 1 | m | u | D. to Y. - | { *Pachyodon*, *C. la lata*, Stutch. *C. philea*, d'Orb. |
| — — copides, de Ryck - | | | 2 | | | | | | | | | | 1 | | | Le. Li. | |
| — — crassissima, Sow. - | | | 2 | 3 | 4 | | | 7 | | | | | 1 | m | | D. to Y. - | *C. ingens*, Tawn. |
| — — crassiuscula, Sow. - | | 1 | 2 | | | | | 7 | | | | | 1 | m | | S. to Y. | |
| — — cuneata, Stutch. - | | | | | | 5 | | 7 | | | | | 1 | m | | D. Nn. Li. | |
| — — gigantea, Quenst. - | | | 2 | | | | | 7 | | | | | 1 | m | | D. Le. Li. | |
| — — ingens, Tawn. - - | | 1 | | | | | | | | | | | 1 | | | Gl. | |
| — — Listeri, Sow. - - | | | 2 | 3 | | | | | | | | | 1 | | | D. to Y. | |
| — — — var. hybrida. Sow. | | | 2 | 3 | 4 | 5 | | 7 | | | | | 1 | | | D. G. to Y. | |
| — — — var. ovalis, Stutch. | | 1 | 2 | | | | | | | | | | 1 | | | S. to Y. | |
| — — rugulosa, Tate - - | | | | | 4 | | | | | | | | 1 | | | S. | |
| — — Slatteri, Walford - | | | | | | | | 7 | | | | | | m | | Nn. Le. - | *Isocardia.* |
| — — suttonensis, Tawn - | × | 1 | 2 | | | | | | | | | | 1 | | | S. Gl. - | *C. regularis*, Terq |
| Cardita consimilis, Tate - | | | | | 4 | | | | | | | | 1 | | | S. | |
| — — Heberti, Terq. - - | | | 2 | | | | | | | | | | 1 | | | Gl. Li. Y. | |
| — — multicostata, Phil. - | | | 2 | 3 | 4 | | 6 | 7 | | | | | 1 | m | | D. to Y. - | *C. liasiana*, Moor |
| — — rhomboidalis, Tawn. - | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| — — tetragona, Terq. - | | | 2 | | | | | | | | | | 1 | | | Gl. - - | *Astarte Dun* Tawn. |
| Cardium substriatulum, d'Orb. | | | | | | | | 7 | | | 10 | 11 | | m | u | N. Le. Y. - | *Protocardium.* |
| — — truncatum, Sow. - | | | | | 4 | 5 | 6 | 7 | 8 | | | | 1 | m | u | D. to Y. - | *Protocardium.* |
| Ceromya bombax, Quenst. | | | | | 4 | | | 7 | 8 | | | | 1 | m | u | S. to Y. - | *Venus.* |

| Species. | Rhaetic Beds. | Lower. Am. planorbis. | Lower. Am. Bucklandi. | Lower. Am. oxynotus. | Lower. Am. Jamesoni. | Lower. Am. capricornus. | Middle. Am. margaritatus. | Middle. Am. spinatus. | Upper. Am. annulatus. | Upper. Am. serpentinus. | Upper. Am. communis. | Upper. Am. jurensis. | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| **Mollusca**—*cont.* | | | | | | | | | | | | | | | | | |
| *Lamellibranchiata*—cont. | | | | | | | | | | | | | | | | | |
| Ceromya gibbosa, Eth. - | | | 2 | | | | | | | | | | 1 | ? | | O. Y. | |
| — petricosa, Simps. - | | | | | | | 6 | 7 | 8 | | | | | m | u | S. G. O. Li. Y. | *Isocardia liassica*, Moore. |
| *Corbis*, see Leda. | | | | | | | | | | | | | | | | | |
| Corbula somersetiensis, Moore. | | | | | | | | | | 9 | | | | | u | S. | |
| *Corimya*, see Thracia. | | | | | | | | | | | | | | | | | |
| *Crenatula*, see Inoceramus. | | | | | | | | | | | | | | | | | |
| Cucullæa cancellata, Phil. - | | | | | | | 6 | | 8 | | 10 | | | m | u | × D. O. Nn. | |
| — elongata, Sow. - - | | | | | | | 6 | | | | | | | m | | × D. | |
| — ferruginea, Lyc. - | | | | | | | | | | | 10 | | | | u | × Li. | |
| — Münsteri, Ziet. - | | | | 3 | 4 | 5 | | 7 | 8 | | | | 1 | m | u | S. to Y. | |
| — olivæformis, Lye. - | | | | | | | | | | | | 11 | | | u | G. | |
| — ovum, Quenst. - - | | | 2 | | | | | | | | | | 1 | | | Li. | |
| — transversa, Moore - | | | | | | | | 7 | | | | | | m | | S. | |
| — see also Macrodon. | | | | | | | | | | | | | | | | | |
| Cypricardia cucullata, Münst. | | | | | 4 | 5 | 6 | 7 | 8 | | | | 1 | m | u | D. to Y. - | Very near to *C. intermedia*, Moore. |
| — intermedia, Moore - | | | | | 4 | 5 | 6 | 7 | | | | | 1 | m | | S. G. O. Li. | *C. pellucida*, Moore. |
| — Winwoodi, Moore - | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| *Cyprina*, see Lucina. | | | | | | | | | | | | | | | | | |
| Exogyra Berthaudi, Dum. | | | | | | | | | | 9 | | | | | u | O. | |
| — virguloides, Tate - | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| Gervillia acuminata, Terq. | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| — betacalcis, Quenst. - | | | 2 | | | | | | | | | | 1 | | | Li. | |
| — crassa, Buckm. - | | | | 3 | | | | | | | | | 1 | | | G. | |
| — Hagenovi, Dunk. - | | 1 | 2 | 3 | | | | | | | | | 1 | | | S. Y. | |
| — fornicata, Lyc. - | | | | | | | | | | | | 11 | | | u | G. | |
| — incurva, Moore - | | | | | | | | | | 9 | | | | | u | S. | |
| — lævis, Buckm. - - | | | | | 4 | 5 | | | | | | | 1 | | | G. Wk. Li. | |
| — lanceolata, Sow. - | | | 2 | 3 | | | | | | | | | 1 | | | × D. | |
| — oblonga, Moore - | | | | | | | | | | 9 | | | | | u | S. | |
| Goniomya heteropleura, Ag. | | | 2 | | | | | 7 | | | | | 1 | m | | D. G. Nn. Le. Y. | *G. rhombifera*, Quenst. |
| — hybrida, Münst. - | | | | | 4 | 5 | 6 | 7 | 8 | | | | 1 | m | u | × G. to Y. | |
| Gresslya abducta, Phil. - | | | | | | | | | | | | 11 | | | u | × Nn. Y. | |
| — donaciformis, Phil. - | | | | | | | 6 | 7 | | 9 | 10 | 11 | | m | u | S. G. Li. Nn. Y. | *Myacites*. |
| — galathea, Ag. - | | | 2 | 3 | | | | | | | | | | | | S. G. Y. - | *Pleuromya*. |

| Species. | Rhætic Beds. | Lower. Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Middle. Am. margaritatus. | Am. spinatus. | Upper. Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 6 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| Mollusca—*cont.* | | | | | | | | | | | | | | | | | |
| *Lamellibranchiata*—cont. | | | | | | | | | | | | | | | | | |
| Gresslya intermedia, Simps. | | | | | | | 6 | 7 | | | | | | m | | G. Le. Li. Y. | |
| —— lunulata, Tate - - | | | | 4 | | 6 | 7 | | | | | | 1 | m | | Wk. Le. Li. Y. | |
| —— punctata, Simps. - | | | | | 4 | | | | | | | | 1 | | | Wk. Y. | |
| —— Seebachi, Brauns. - | | | | | | | 6 | | | | | | | m | | Li. Y. | |
| —— striata, Ag. - - | | | | | 4 | | | | | | | | 1 | | | Wk. Y. | |
| Gryphæa arcuata, Lam. - | | 1 | 2 | 3 | 4 | | | | | | | | 1 | | | D. to Y. - | *Ostrea* (of some thors). *G. incurva*, Sow |
| —— cymbium, Lam. - | | | 2 | 3 | 4 | 5 | 6 | 7 | | | | | 1 | m | | D. to Y. - | *G. MacCullochi*, Sc |
| —— —— var. depressa, Phil. | | | | | | 5 | 6 | 7 | | | | | 1 | m | | S. Le. Y. | |
| —— —— var. obliquata, Sow. | | | | 3 | 4 | 5 | | | | | | | 1 | m | | G. Wk. Le. Y. | |
| —— gigantea, Sow. - - | | | | | | 5 | 6 | 7 | | | | | 1 | m | | D. to Li. | |
| Harpax Parkinsoni, Quenst. | | | | | | | | | | | | 11 | | | u | S. | |
| —— see also Plicatula. | | | | | | | | | | | | | | | | | |
| *Hettangia*, see Tancredia. | | | | | | | | | | | | | | | | | |
| Hinnites Davoei, Dum. - | | | | | | | | 7 | | | | | | m | | O. | |
| —— tuberculosus, Goldf. - | | | | | | | | | | | | | 1 | | | D. | |
| —— tumidus, Ziet. - - | | | | | 4 | 5 | 6 | 7 | 8 | 9 | | | 1 | m | u | × D. to Y. - | *H. velatus*, Goldf. |
| Hippopodium ovalis, Moore | | | | | | | | 7 | | | | | | m | | S. | |
| —— ponderosum, Sow. - | | | 2 | 3 | 4 | 5 | 6 | 7 | | | | | 1 | m | | S. to Y. - | *H. ferri*, Eth., *lus hippocampu* & B. |
| Homomya - - - | | | | | | | | 7 | | | | | | m | | G. | |
| Inoceramus cinctus, Münst. | | | | | | | | | 8 | 9 | 10 | | | | u | O. Nn. Y. | |
| —— dubius, Sow. - - | | | | | | | | 7 | 8 | 9 | | | 1 | m | u | S. to Y. | |
| —— incurvatus, Tate - | | | | | | 5 | | | | | | | 1 | | | G. | |
| —— pinnæformis, Dunk. - | | | 2 | | | | | | | | | | 1 | | | D. Y. | |
| —— plicatus, Moore - | | | | | | | | | | | 10 | | | | | S. | |
| —— substriatus, Münst. - | | | | | 4 | 5 | 6 | 7 | 8 | | | | 1 | m | u | G. to Y. | |
| —— tiltonensis, Wilson - | | | | | | | | 7 | | | | | | m | | Le. | |
| —— ventricosus, Sow. - | | | | | 4 | 5 | | | | | | | 1 | | | D. to Y. - | *Crenatula.* |
| *Isocardia*, see Astarte, Cardinia, and Ceromya. | | | | | | | | | | | | | | | | | |
| Leda complanata, Goldf. - | | | | 3 | 4 | 5 | 6 | 7 | | | | | 1 | m | | S. to Y. - | *Nucula.* |
| —— Galathea, d'Orb. - | | | 2 | 3 | 4 | 5 | 6 | 7 | 8 | | | | 1 | m | u | S. to Y. | *L. Quenstedti*, T *Nucula inflex* Quenst. |
| —— graphica, Tate - - | | | | | 4 | 5 | 6 | 7 | | | | | 1 | m | | G. Wk. O. Li. Y. | *L. longicaudata*, Simps. |

| Species. | Rhætic Beds. | Lower. | | | | | Middle. | | Upper. | | | | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Am. margaritatus. | Am. spinatus. | Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | | | | | |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| Mollusca—*cont.* | | | | | | | | | | | | | | | | | |
| *Lamellibranchiata*—cont. | | | | | | | | | | | | | | | | | |
| Leda imbricata, Sharman & Newton. (MS.) | | | | | | | 6 | | | | | | | m | | Li. | |
| —— minor, Simps. - - | | | | 3 | 4 | 5 | 6 | | | | | | 1 | m | | G. Wk. to Y. | |
| —— ovum, Sow. - - | | | | | | | | | | | 10 | | | | u | G. to Y. - | *Nucula.* |
| —— Renevieri, Oppel - | | | 2 | 3 | | | | | | | | | 1 | | | Wo. Y. - | *L. tenuistriata* Piette. |
| —— subovalis, Goldf. - | | | 2 | 3 | 4 | | | 7 | | | | | 1 | m | u | G. Wk. Nn. · Y. | { *L. Bronni*, An… *Nucula, Corb…* *formis*, Phi… |
| —— Zieteni, Brauns. - | | | | 3 | 4 | 5 | 6 | | | | | | 1 | m | | G. Wo. Wk. Li. Y. | { *Nucula acumi…* Goldf. *N. inflata*, Zi… |
| Lima amnifera, Whidb. - | | | | | | | | | | | | 11 | | | u | S. | |
| —— angusta, Tawn. - | | | 2 | | | | | | | | | | 1 | | | Gl. Li. | |
| —— compressa, Wright - | | | | | | | | | | | | | 1 | | | G. | |
| —— cubiferens, Whidb. - | | | | | | | 6 | | | | | | | m | | D. | |
| —— densicosta, Quenst. - | | | | | | | | | | | | | | | | S. - - | Horizon doubtf… |
| —— dentata, Terq. - - | | | 2 | | | | | | | | | | 1 | | | Gl. Li. - | *L. planicostata*, … |
| —— Deslongchampsi, Stol. | | | 2 | | | | | | | | | | | | | S. - - | Horizon doubtf… |
| —— dunravenensis, Tawn. | | | | | | | | | | | | | 1 | | | Gl. - - | ? *L. gigantea*, S… |
| —— duplicata, Sow. - | | 1 | 2 | | | | | 7 | | | | | 1 | m | | × S. Gl. G. Nn. | *L. subduplicata*, … |
| —— electra, d'Orb. - - | | | | | | | | | | | | 11 | | | u | × G. | |
| —— eucharis, d'Orb. - | | | | | 4 | | 6 | 7 | 8 | 9 | | | 1 | m | u | S. to Y. | |
| —— galathea, d'Orb. - | | | | | | | | | | | | 11 | | | u | G. | |
| —— gigantea, Sow. - - | | 1 | 2 | 3 | 4 | | | | | | | | 1 | | | D. to Y. | |
| —— Hermanni, Voltz - | | | 2 | | 4 | 5 | 6 | 7 | 8 | | | | 1 | m | u | D. to Y. | |
| —— hettangiensis, Terq. - | | 1 | 2 | | 4 | | | 7 | | | | | 1 | m | | D. to Y. | |
| —— Omaliusi, Chap. & Dew. | | | | | | | | 7 | | | | | | m | | G. | |
| —— ornata, Lyc. - - | | | | | | | | | | | | 11 | | | u | G. | |
| —— pectinoides, Sow. - | | 1 | 2 | 3 | 4 | | 6 | 7 | 8 | | | | 1 | m | u | D. to Y. | |
| —— planicostata, Tawn. - | | 1 | | | | | | | | | | | 1 | | | Gl. | |
| —— punctata, Sow. - | | 1 | 2 | | | | 6 | 7 | | | | | 1 | m | | × D. to Y. | |
| —— scabricula, Tate - | | | | | 4 | | | | | | | | 1 | | | S. G. Wk. | |
| —— strigillata, Laube. - | | | | | | | | | | | | 11 | | | u | × G. | |
| —— succincta, Schloth. - | | | 2 | | 4 | | 6 | 7 | | | | | 1 | m | | D. to Y. - | *L. antiquata*, S… |
| —— tuberculata, Terq. - | | 1 | 2 | | | | | 7 | | | | | 1 | m | | D. S. Gl. Li. Y. | *L. Terquemi*, Ta… |
| —— toarcensis, Desl. - | | | | | | | | | | | | 11 | | | u | S. Nn. Y. | |
| Limea acuticosta, Münst. | | | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | | | 1 | m | u | D. to Y. | |

| Species. | Rhætic Beds. | Lower. Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Middle. Am. margaritatus. | Am. spinatus. | Upper. Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MOLLUSCA—*cont.* | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| *Lamellibranchiata*—cont. | | | | | | | | | | | | | | | | | |
| Limea cristata, Dum. - | | | | | | | | 7 | | | | | | m | | O. | |
| —— juliana, Dum. - - | | | | | 4 | | | 7 | 8 | | | | 1 | m | u | O. Nn. Le. Y. | |
| Lithodomus - - - | | | 2 | | | | | 7 | | | | 11 | 1 | m | u | D. Gl. Li. Nn. | |
| Lucina bellona, d'Orb. - | | | | | | | | | | 9 | | 11 | | | | × Nn. | |
| —— normalis, Tawn. - | | | 2 | | | | | | | | | | 1 | | | Gl. - - | *Cyprina.* |
| —— pumila, Münst. - | | | | | 4 | | 6 | 7 | 8 | 9 | | | 1 | m | u | D. to Nn. Y. | *Venus.* |
| Macrodon Buckmani, Rich. | | | | | 4 | 5 | 6 | 7 | 8 | | | | 1 | m | u | G. to Y. - | *Arca elongata*, Que |
| —— hettangiensis, Terq. - | | 1 | 2 | | | 5 | | | | | | | 1 | m | | S. G. O. Li. Y. | { *Arca Lycetti*, M<br>*Cucullæa.* |
| —— intermedius, Simps. - | | | | 3 | 4 | 5 | 6 | 7 | | | | | 1 | m | u | × D. to Y. - | { *A. numismalis*, T<br>*Cucullæa cucul*<br>Portl.<br>*C. bilineata*, Mo |
| —— pulchellus, Tate - | | | | | 4 | | | | | | | | | | | G. Y. | |
| —— pullus, Terq. - - | | | 2 | | | | | | 8 | | | | | | u | O. Nn. Y. - | *Arca.* |
| —— undatus, Walf. - | | | | | | | | 7 | 8 | | | | | m | u | Nn. | |
| Modiola Beesleyi, Tate - | | | | | | 5 | | | | | | | | | | O. Nn. | |
| — compressa, Goldf. - | | | | | | | | | | | | 11 | | | u | × G. | |
| —— cuneata, Sow. - - | | | | | | | | | | | | 11 | | | u | × G. | |
| —— dorso-plicata, Moore - | | | | | | | | | | 9 | | | | | | S. | |
| —— hillana, Sow. - - | | 1 | 2 | | | | 6 | | | | | | | m | | S. to Y. - | *Mytilus.* |
| —— hillanoides, Chap. & Dew. | | | 2 | | | | | | | | | | | | | Le. Y. - | *M. oxynoti*, Quen |
| —— imbricato-radiata, Tawn. | | 1 | 2 | | | | | | | | | | | | | Gl. - - | *Mytilus.* |
| —— lævis, Sow. - - | | 1 | 2 | | | | | | | | | | | | | G. Le. Y. | |
| —— minima, Sow. - - | × | 1 | 2 | | | | | | | | | | | | | D. to Le. Y. | |
| —— numismalis, Oppel - | | | | 3 | 4 | 5 | 6 | 7 | 8 | | | | | m | u | G. to Y. | |
| —— sowerbyana, d'Orb. - | | | | | | | | | | | | 11 | | | u | × G. | |
| —— ornata, Moore - - | | | | | | | | 7 | | | | | | | | S. | |
| —— oxynoti, Quenst. - | | | 2 | | | | | | | | | | | | | Li. | |
| —— scalprum, Sow. - | | | 2 | 3 | 4 | 5 | 6 | 7 | | | | | | m | u | × S. to Y. | |
| —— subcancellata, Buv. - | | | | | | | 6 | 7 | 8 | | | | | m | u | S. O. to Y. - | *M. ornata*, Moore |
| Monotis decussata, Münst. | × | 1 | 2 | | | | | | | | | | | | | S. Gl. Li. - | *Avicula.* |
| —— fallax, Pflücker - | | 1 | | | | | | | | | | | | | | Wk. Y. - | *Avicula* = *Monot cussata* of authors. |
| —— see also Avicula. | | | | | | | | | | | | | | | | | |
| *Myacites*, see also Gresslya and Pleuromya. | | | | | | | | | | | | | | | | | |

| Species. | Rhætic Beds. | Lower. Am. planorbis. | Lower. Am. Bucklandi. | Lower. Am. oxynotus. | Lower. Am. Jamesoni. | Lower. Am. capricornus. | Middle. Am. margaritatus. | Middle. Am. spinatus. | Upper. Am. annulatus. | Upper. Am. serpentinus. | Upper. Am. communis. | Upper. Am. jurensis. | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mollusca—*cont.* | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| *Lamellibranchiata*—cont. | | | | | | | | | | | | | | | | | |
| Myoconcha crassa, Sow. - | | | | | | | | | | | | 11 | | | u | × G. | |
| —— decorata, Münst. - | | | | | 4 | 5 | | 7 | 8 | | | | l | m | u | D. S. Wk. O. Y. | |
| —— oxynoti, Quenst. - | | | 2 | | | | | | | | | | l | | | S. Li. | |
| —— psilonoti, Quenst. - | | 1 | 2 | | | | | | | | | | l | | | S. Y. | |
| Myophoria postera, Quenst. | × | | 2 | | | | | | | | | | l | | | Gl. | |
| **Mytilus aviothensis**, Buv. - | | | | | | | | 7 | 8 | | | | | m | u | O. Nn. Y. | |
| —— see also Modiola. | | | | | | | | | | | | | | | | | |
| **Nucula claviformis**, Sow. - | | | | | | | | | | 9 | | | | | | G. Nn. | |
| —— cordata, Goldf. - - | | | | | 4 | 5 | | 7 | 8 | 9 | | | l | m | u | D. to Y. | |
| —— Hammeri, Defr. - | | | | | | | | | | 9 | 10 | | | | u | G. O. Nn. Li. | { *N. Hausmanni*, Roem. *N. subglobosa*, Roem. |
| —— jurensis, Quenst. - | | | | | | | | | | | | 11 | | | u | G. | |
| —— navis, Piette - - | | | 2 | 3 | | | | | | | | | l | | | D. Wo. Y. | |
| —— ungulella, Tate - | | | | 3 | 4 | 5 | 6 | | 8 | | | | l | m | u | S. G. to Le. | |
| —— see also Leda. | | | | | | | | | | | | | | | | | |
| **Opis carusensis**, d'Orb. - | | | | | 4 | | | | | | | | | m | | G. | |
| —— curvirostris, Moore - | | | | | | | | | | 9 | | | | m | u | S. Nn. | |
| —— Deslongchampsi, Tate | | | | | | | | 7 | | | | | | m | | G. | |
| —— triangularis, Moore - | | | | | | | | | | | | | | | | S. - - | Horizon doubtful. |
| **Ostrea Goldfussi**, Bronn - | | | 2 | 3 | 4 | 5 | | | | | | | l | | | S. to Y. | |
| —— irregularis, Münst. - | × | 1 | 2 | | | | 6 | | | | | | l | m | | D. to Y. - | *Anomia socialis*, Tawn.; *O. lævis*, Tawn. |
| —— liassica, Strickl. - | × | 1 | 2 | | | | | | | | | | l | | | D. to Y. - | *O. sublamellosa*, Dunk. |
| —— multicostata, Münst. - | | 1 | 2 | | | | | | | | | | l | | | D. S. Gl. - | *Terquemia arietis*, Quenst. |
| —— sandalina, Goldf. - | | | | | | | | | | | | 11 | | | u | Nn. | |
| —— semiplicata, Münst. - | | | 2 | | 4 | | | | | | | | l | | | S. Wo. Wk. Y. | |
| —— sportella, Dum. - | | | | | | | | 7 | 8 | | | | | m | u | O. Nn. Y. | |
| —— subauricularis, d'Orb. | | | | | | | | | 8 | 9 | 10 | 11 | | | u | N. R. Y. | |
| —— submargaritacea, Brauns. | | | | | | | 6 | 7 | 8 | | | | | m | u | O. Nn. Le. Y. | |
| —— see also Gryphæa and Plicatula. | | | | | | | | | | | | | | | | | |
| ***Pachyodon***, see Cardinia. | | | | | | | | | | | | | | | | | |
| ***Panopæa***, see Arcomya. | | | | | | | | | | | | | | | | | |
| **Pecten æqualis**, Quenst. - | | 1 | | 3 | | 5 | | | | | | | l | | | G. Li. Y. | |
| —— æquivalvis, Sow. - | | | | | 4 | 5 | 6 | 7 | 8 | | | | l | m | u | D. to Y. - | *P. sublævis*, Y. & B. |

| Species. | Rhætic Beds. | Lower. | | | | | Middle. | | Upper. | | | | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Am. margaritatus. | Am. spinatus. | Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | | | | | |
| Mollusca—*cont.* | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| *Lamellibranchiata*—cont. | | | | | | | | | | | | | | | | | |
| Pecten æquivalvis, var. dentatus, Sow. | | | | | | | | 7 | 8 | | | | l | m | | D. S. G. Nn. Le. | |
| —— calvus, Goldf. - - | | | 2 | 3 | 4 | 5 | 6 | 7 | | | | | l | m | | D. to Y. - | { *P. subulatus*, Mün *P. Hehli*, d'Orb. |
| —— cingulatus, Goldf. - | | | | | | | | 7 | | | | | | m | | Le. | |
| —— demissus, Phil. - | | | 2 | | | | | 7 | | | | 11 | l | m | u | S. Li. | |
| —— julianus, Dum. - | | | | | | | | 7 | | | | | | m | u | S. Nn. | |
| —— lunularis, Roem. - | | 1 | 2 | | 4 | 5 | 6 | 7 | 8 | | | | l | m | u | D. to Y. - | *P. liasinus*, Nyst. |
| —— pollux, d'Orb. - - | | 1 | 2 | | | | | | | | | | l | | | S. Gl. Y. | *P. suttonensis*, Taw near to *P. valo ensis*, Defr. |
| —— pradoanus, de Vern. - | | | 2 | | | | | | | | | | l | | | Wk. | |
| —— priscus, Schloth. - | | | | 3 | 4 | 5 | | 7 | 8 | | | | l | m | | S. to Y. | |
| —— pumilus, Lam. - - | | | | | | | | | 8 | 9 | 10 | 11 | | | u | × O. Nn. Y. | *P. personatus*, Ziet. |
| —— punctatissimus, Quenst. | | | 2 | | | | | | | | | | l | | | Li. Y. | |
| —— substriatus, Roem. - | | | | | 4 | 5 | 6 | 7 | 8 | | | | l | m | u | S. O. Wk. Nn. Li. Y. | |
| —— textilis, Münst. - | | | 2 | | | | | | | | | | l | | | G. Y. | |
| —— textorius, Schloth. - | | | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | | | l | m | u | × D. to Y. | |
| —— texturatus, Münst. - | | | 2 | | | | | | | | | | l | | | × S. Gl. Li. | *P. Etheridgei*, Tawn |
| —— Thiollieri, Mart. - | | | 2 | | | | | | | | | | l | | | S. G. Li. Y. | |
| Perna dubia, Moore - | | | | | | | | | 8 | | | | | | | S. | |
| —— infraliassica, Quenst. - | | | 2 | | | | 6 | | | | | | l | | | G. Le. Nn. Y. | |
| —— lugdunensis, Dum. - | | | | | | | | 7 | | | | | | m | | S. O. Nn. Y. | ? *P. antiqua*, Moore |
| —— ? Ramsayi, Tawn. - | | | 2 | | | | | | | | | | l | | | Gl. | |
| —— rugosa, Goldf. - - | | | | | | | | | | | | 11 | | | u | G. | |
| Pholadomya ambigua, Sow. | | | 2 | | 4 | 5 | 6 | 7 | | | | | l | m | u | D. to Y. | |
| —— decorata, Ziet. - - | | | | | 4 | 5 | 6 | | | | | | l | | | G. Wk. Le. Y. | |
| —— Fraasi, Oppel - - | × | | 2 | | | | | | | | | | l | | | G. Li. Y. - | *P. prima*, Quenst. |
| —— glabra, Ag. - - | | 1 | 2 | | | | | | | | | | l | | | S. G. Gl. Le. Y. | |
| —— Hausmanni, Münst. - | | | | | | 5 | | | | | | | l | | | G. Li. | |
| —— Simpsoni, Tate - | | | | | | | | 7 | | | | | | m | | G. Y. | |
| —— ventricosa, Ag. - | | | 2 | 3 | | | | | | | | | l | | | S. Le. Y. | |
| Pinna folium, Y. & B. - | | | | 3 | 4 | | 6 | | | | | | l | m | | S. to Y. - | *P. fissa*, Goldf. |
| —— Hartmanni, Ziet. - | | | 2 | 3 | | | 6 | 7 | | | | | l | m | | × D. S. Gl. Li. Y. | |
| —— semistriata, Terq. - | | | 2 | | | | | | | | | | l | | | D. S. Gl. - | *P. insignis*, Tawn. |

| Species. | Rhætic Beds. | Lower. | | | | | Middle. | | Upper. | | | | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Am. margaritatus. | Am. spinatus. | Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | | | | | |
| MOLLUSCA—*cont.* | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| *Lamellibranchiata*—cont. | | | | | | | | | | | | | | | | | |
| Pinna spathulata, Tate - | | | | | | | | 7 | | | | | | m | | O. Y. | |
| —— tiltonensis, Wils. - | | | | | | | | 7 | | | | | | m | | Le. | |
| Placunopsis liassica, Smithe | | | | | | | | 7 | | | | | | m | | G. | |
| —— sparsicostatus, Lyc. - | | | | | | | | | | | | | | | u | G. | |
| Pleuromya arenacea, Ag. - | | | | | | | | | | 9 | 10 | | | | u | Li. - - | *Myacites.* |
| —— costata, Y. & B. - | | 1 | 2 | | 4 | 5 | 6 | 7 | 8 | 9 | 10 | | l | m | u | D. to Y. - | *P. unioides*, Roem. |
| —— crassa, Ag. - - | | | 2 | | | | | | | | | | l | | | S. Y. | |
| —— crowcombeia, Moore - | × | 1 | | | | | | | | | | | l | | | S. G. Wk. Y. | ? *Anoplophora.* *Myacites musculoides*, Schloth. *Pteromya.* |
| —— elongata, Roem. - | | | | | 4 | | | | | | | | l | | | G. | |
| —— granata, Simps. - | | | | | | | 6 | 7 | | | | | | m | | G. Y. | |
| —— liasina, Schübl. - | | | 2 | | | | | | | | | | l | | | S. Y. | |
| —— mundula, Tate - | | | | | | | 6 | | | | | | | m | | D ?. Y. | |
| —— ovata, Roem. - - | | | | | 4 | 5 | | 7 | | | | | l | m | | S. G. Wk. Y. | |
| —— rotundata, Ziet. - | | | | | | | | | 8 | 9 | | | | m | u | O. Nn. Y. | |
| —— striatula, Ag. - - | | | 2 | 3 | | | | | | | | | l | | | Le. | |
| Plicatula calva, Desl. - | | | | | | 5 | 6 | 7 | | | | | l | m | | O. Y. | |
| —— catinus, Desl. - - | | | | | | | | | | 9 | 10 | | | | u | O. Nn. | |
| —— Deslongchampsi, Terq. | | | 2 | | | | | | | | | | l | | | S. G. | |
| —— intusstriata, Emm. - | × | 1 | 2 | | | | | | | | | | l | | | S. Gl. - | *Ostrea.* |
| —— lævigata, d'Orb. - | | | | | | | 6 | 7 | | | | | | m | | G. Nn. | |
| —— liasina, Terq. - - | | | 2 | | | | | | | | | | l | | | Wk. Y. | |
| —— sarcinula, Münst. - | | | | | 4 | 5 | | 7 | | | | | l | m | | S. G. Wk. Y. | |
| —— spinosa, Sow. - - | | | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | | | l | m | u | D. to Y. - | *Harpax Parkinsoni.* (Bronn), of some authors. |
| Posidonomya Bronni, Voltz | | | | | | | | | 8 | 9 | | | | | u | G. to Y. | |
| Protocardium phillipianum, Dunk. | × | 1 | 2 | 3 | | 5 | | | | | | | l | | | S. Wk. Le. Y. | ? = *Cardium rhæticum*, Merian. |
| —— see also Cardium. | | | | | | | | | | | | | | | | | |
| Pullastra - - - | | 1 | | | | | | | | | | | l | | | S. | |
| Tancredia liassica, Eth. - | | | | | 4 | | | | | | | | l | | | Li. - - | ? *T. broliensis*, Buv. |
| —— ovata, Chap. & Dew. - | | | 2 | | | 5 | | | | | | | l | | | Li. Y. - | *T. ferrea*, Eth. |
| Tellina lingonensis, Dum. - | | | | | | | | 7 | 8 | | | | | m | u | O. Y. | |
| *Terquemia*, see Ostrea. | | | | | | | | | | | | | | | | | |
| Thracia glabra, Ag. - | | | | | | | | | | | 10 | | | | u | O. Nn. Y. - | *Corimya.* |
| Trigonia lingonensis, Dum. | | | | | | | | 7 | 8 | | | | | m | u | O. Nn. Y. | |

| Species. | Rhætic Beds. | Lower. Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Middle. Am. margaritatus. | Am. spinatus. | Upper. Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MOLLUSCA—*cont.* | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| *Lamellibranchiata*—cont. | | | | | | | | | | | | | | | | | |
| Trigonia northamptonensis, Walford. | | | | | | | | | | | 10 | | | | u | Nn. | |
| —— pulchella, Ag. | | | | | | | | | | | 10 | | | | u | Nn. Li. | |
| Unicardium cardioides, Phil. | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | | | | l | m | | D. to Y. | |
| —— subglobosum, Tate | | | | | | | | 7 | 8 | 9 | | | | m | u | S. Le. to Y. | *U. globosum*, Moc |
| *Venus*, see Ceromya. | | | | | | | | | | | | | | | | | |
| BRACHIOPODA. | | | | | | | | | | | | | | | | | |
| Crania Griffini, Dav. | | | | | | | | 7 | | | | | | m | | Nn. | |
| —— Gumberti, Desl. | | | | | | | 6 | | | | | | | m | | S. | |
| —— liassica, Moore | | | 2 | | | | | | | | | | l | | | S. G. Gl. | |
| —— Moorei, Dav. | | | | | | | | | | 9 | | | | | u | S. | |
| Discina babeana, d'Orb. | × | | 2 | | | | | | | | | | l | | | G. | *D. Townshendi*, Fo |
| —— Davidsoni, Moore | | | 2 | | | | | | | | | | l | | | S. G. Gl. | |
| —— Holdeni, Tate | | | 2 | | 4 | | | | | | | | l | | | G. Wk. Y. | |
| —— reflexa, Sow. | | | | | | | | ? | | 9 | 10 | 11 | | m | u | × D. to Y. | *D. orbicularis*, M *Orbicula.* |
| Koninckella Bouchardi, Dav. | | | | | 4 | 5 | 6 | 7 | | | | | l | m | | S. | *Leptæna.* |
| —— liasiana, Bouch. | | | | | | | | 7 | | | 10 | | | m | u | D. S. G. | |
| Leptæna Davidsoni, Desl. | | | | | | | | | | 9 | | | | | u | S. | |
| —— Moorei, Dav. | | | | | | | | | | 9 | 10 | | | | u | S. G. | |
| —— rostrata, E. Desl. | | | | | 4 | | 6 | | | | | | l | m | | S. | |
| Lingula Beani, Phil. | | | | | | | | | | | 10 | 11 | | | u | S. Nn. | |
| —— Davidsoni, Oppel | | | | 3 | | | 6 | | | | | | l | m | | G. | |
| —— longovicensis, Terq. | | | | | | | | | | | 10 | 11 | | | u | Nn. Y. | |
| —— metensis, Terq. | | | 2 | 3 | | | | | | | | | l | | | G. | |
| —— sacculus, Chapw. & Dew. | | | | | 4 | 5 | 6 | 7 | | | | | l | m | | D. S. G. Wk. Y. | |
| Rhynchonella acuta, Sow. | | | | | 4 | | 6 | 7 | | | | | l | m | | D. S. G. Nn. Y. | |
| —— var. bidens, Phil. | | | | | | | | 7 | | | | | | m | | Le. | |
| —— amalthei, Quenst. | | | | | | | 6 | 7 | 8 | 9 | | | | m | u | S. G. O. Nn. Le. | |
| —— Bouchardi, Dav. | | | | | | | | | 8 | 9 | | | | | u | D. S. O. Nn. Li. Y. | |
| —— calcicosta, Quenst. | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | | | | l | m | | D. to Y. | (= *R. variabili* of authors.) |
| —— Deslongchampsi, Dav. | | | | | | | | | | | | | | m | | S. | |
| —— egretta, E. Desl. | | | | | | | 6 | | | | | | | m | | D. S. | |

| Species. | Rhætic Beds. | Lower. | | | | | Middle. | | Upper. | | | | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Am. margaritatus. | Am. spinatus. | Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | | | | | |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| ACHIOPODA—*cont.* | | | | | | | | | | | | | | | | | |
| :honella fallax, E. Desl. | | | | | | | 6 | | | | | | | m | | D. S. | |
| xdinalis, Tate - - | | | | | | | 6 | 7 | | | | | | m | | S. O. Nn. Wk. Le. Y. | |
| ırcillata, Von Buch - | | | | | 4 | | 6 | 7 | | | | | 1 | m | | D. S. G. Wk. Y. | |
| levensis, Smithe - | | | 2 | | | | | | | | | | 1 | | | G. | |
| ırensis, Quenst. - | | | | | | | | | | 9 | 10 | 11 | | | u | D. O. Nn. Y.? | |
| neata, Y. & B. - | | | | | | | 6 | 7 | | | | | | m | | O. Y. | |
| —— var. radstockiensis, Dav. | | | | | | | 6 | | | | | | | m | | S. G. | |
| foorei, Dav. - - | | | | | | | 6 | 7 | | 9 | | 11 | | m | u | D. S. O. Li. | |
| xynoti, Quenst. - | | | | 3 | 4 | 5 | | 7 | | | | | 1 | m | | G. Nn. Y. | |
| licatissima, Quenst. - | | | 2 | 3 | 4 | 5 | | | | | | | 1 | | | S. Wk. Le. Y. | |
| ygmæa, Mor. - - | | | | | | | | | | 9 | 10 | | | | u | S. G. | |
| imosa, von Buch - | | | | | 4 | 5 | 6 | 7 | | | | | 1 | m | | S. G. Wk. Y. | |
| errata, Sow. - - | | | | | | | 6 | 7 | | | | | | m | | D. S. | |
| ubeconcinna, Dav. - | | | | | 4 | 5 | 6 | 7 | | | | | 1 | m | | D. S. Wk. Nn. Y. | |
| etrahedra, Sow. - | | | | 3 | 4 | 5 | 6 | 7 | 8 | | | | 1 | m | u | D. to Y. | |
| —— var. curviceps, Quenst. | | | | | 4 | | 6 | | | | | | 1 | m | | Wk. | |
| —— var. dumbletonensis, Walker | | | | | | | 6 | 7 | | | | | | m | | G. | |
| —— var. northamptonensis, Walker. | | | | | | | 6 | 7 | 8 | | | | | m | u | Nn. Le. | |
| ariabilis, Schloth. - | | | 2 | 3 | 4 | 5 | 6 | 7 | | | | | 1 | m | u | D. to. Y. - | (See *R. calcicosta.*) |
| erina adscendens, sl. - | | | | | | | | | | | | | | m | | D. | |
| Deslongchampsi, Dav. | | | | | | | | | | | | | | m | | S. | |
| Hartmanni, Ziet. - | | | | | | 5 | | | | | | | 1 | | | S. | |
| lminsterensis, Dav. - | | | | | | | | | | | 10 | | | | u | S. G. | |
| Münsteri, Dav. - | | | | | | | 6 | 7 | | | 10 | | | m | u | D. S. G. | |
| oxygona, E. Desl. - | | | | | | | 6 | 7 | | | | | | m | | S. O. N. | |
| oxyptera, Buv. - | | | | | 4 | | | | | | | | 1 | | | Wk. Y. | |
| inguis, Ziet. - - | | | 2 | | 4 | | | 7 | | | | | 1 | m | | D. S. Wk. | |
| ostrata, Schloth. - | | | 2 | | 4 | 5 | 6 | 7 | 8 | | | | 1 | m | u | D. to Y. | |
| errucosa, von Buch. | | | | 3 | 4 | | 6 | | | | | | 1 | m | | S. G. Wk. Le. Y. | |
| Walcotti, Sow. - | | | 2 | 3 | 4 | | 6 | 7 | | | | | 1 | m | | D. to Y. | |

| Species. | Rhætic Beds | Lower. Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Middle. Am. margaritatus. | Am. spinatus. | Upper. Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| Brachiopoda—*cont.* | | | | | | | | | | | | | | | | | |
| Suessia imbricata, E. Desl. | | | | | | | 6 | | | | | | | m | | S. | |
| Terebratula globulina, Dav. | | | | | | | 6 | 7 | | 9 | 10 | | | m | u | S. G. | |
| —— Jauberti, E. Desl. | | | | | | | 6 | | | | | | | m | | S. | |
| —— punctata, Sow. | | | | | 4 | 5 | 6 | 7 | 8 | | | | l | m | | × D. to Y. | |
| —— —— var. Edwardsi, Dav | | | | | 4 | | 6 | 7 | 8 | | | | l | m | | D. to Le. Y. | |
| —— —— var. haresfieldensis, Dav. | | | | | | | | 7 | | | | 11 | | m | | G. Le. | |
| —— —— var. radstockiensis, Dav | | | | | 4 | | 6 | 7 | | | | | l | m | | S. to Le. | |
| —— —— var. subpunctata, Dav. | | | | | | | | 7 | | | | | | m | | D. to Li. | |
| —— Walfordi, Dav. | | | | | | | 6 | 7 | 8 | | | | | m | | O. Nn. Le. | |
| Thecidium, Bouchardi, Dav. | | | | | 4 | 6 | 7 | | | | | | l | m | u | × S. G. | |
| —— Deslongchampsi, Dav. | | | | | | 6 | | | | 9 | | | | m | u | S. | |
| —— Moorei, Dav. | | | 2 | | | 6 | 7 | | | 9 | | | l | m | u | D. S. | |
| —— rusticum, Moore | | | | | | 6 | | | | | | | | m | u | S. G. | |
| —— subserratum, Tate | | | 2 | | | | | | | | | | l | | | Gl. | |
| —— triangulare, d'Orb. | | | | | | 6 | 7 | | | | | | | m | u | × S. Gl. | |
| Waldheimia Bakeriæ, Dav. | | | | | | | 6 | | | | | | | m | | Nn. | |
| —— Darwini, E. Desl. | | | | | 4 | | 6 | 7 | 8 | | | | l | m | u | S. G. O. | |
| —— florella, d'Orb. | | | | | | | 6 | 7 | | | | | | m | | O. Y. | |
| —— heyseana, Dunk. | | | | | 4 | | 6 | | | | | | l | m | | Nn. | |
| —— indentata, Sow. | | | | | 4 | | 6 | 7 | | | | | l | m | | D. to Le. | |
| —— Lycetti, Dav. | | | | | | | | | | 9 | 10 | 11 | | | u | S. G. O. N. Y. | |
| —— Mariæ, d'Orb. | | | | | | | 6 | 7 | | | | | | m | | D. S. G. O. | |
| —— Moorei, Dav. | | | | | | | | 7 | | | | | | m | | D. S. | |
| —— numismalis, Lam. | | | | 3 | 4 | | 6 | 7 | | | | | l | m | | D. to Li. | |
| —— quadrifida, Lam. | | | | | 4 | 5 | 6 | 7 | | | | | l | m | | D. S. G. | |
| —— —— var. cornuta, Sow. | | | | | 4 | 5 | 6 | 7 | | | | | l | m | | D. S. G. | |
| —— perforata, Piette | | | 2 | 3 | 4 | | 6 | 7 | | | | | l | m | | D. to Y. | *W. sarthacensis* d'Orb. |
| —— resupinata, Sow. | | | | | | | 6 | 7 | | | | | | m | | S. to Y. | |
| —— subnumismalis, Dav. | | | | | | | 6 | 7 | | | | | | m | | D. to Le. | |
| —— subovoides, Roem. | | | | | 4 | | 6 | | | | | | l | m | | S. G. Wk. | |
| —— Waterhousei, Dav. | | | | | 4 | 5 | 6 | | | | | | l | m | | S. G. Li. | |
| Zellania, Davidsoni, Moore | | | 2 | | | | | | | | | | l | | | × Gl. | |

| Species. | | Lower. | | | | | Middle. | | Upper. | | | | | | | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Rhætic Beds. | Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Am. margaritatus. | Am. spinatus. | Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | Lower Lias. | Middle Lias. | Upper Lias. | | |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| ACHIOPODA—*cont.* | | | | | | | | | | | | | | | | | |
| ia Laboucherei, Moore. | | | | 2 | | | | | | | | | 1 | | | × Gl. | |
| assica, Mooro | | | | | | | | | | 9 | | | | | | S. | |
| oesa, Moore - | | | | 2 | | | | | | | | | 1 | | | S | |
| POLYZOA. | | | | | | | | | | | | | | | | | |
| pora oolitica, Vine | | | | | | | | 7 | | | | | | m | | × Le. | |
| omatoporoides, Vine | | | | | | 5 | | 7 | 8 | | | | 1 | m | u | O. Le. Nn. - | *D. liassica*, Quenst. |
| riata, Haime | | | | 3 | | | | | | | | | 1 | | | G. - - | *Berenicia.* |
| scina - - - | | | 2 | | | | | | | | | | | | | S. | |
| ora liassica, Tate | | | | | | | | 7 | | | | | | m | | Nn. | |
| topora antiqua, Terq. ette. | | | | 3 | 4 | | | | | | | | 1 | | | G. Wk. | |
| ongata, Walford | | | | | | | | 7 | | | | | | m | | × Nn. | |
| ipora inconstans, ford. | | | | | | | | 7 | 8 | | | | | m | u | O. Nn. | |
| CRUSTACEA. | | | | | | | | | | | | | | | | | |
| *Macroura.* | | | | | | | | | | | | | | | | | |
| Brodiei, H. Woodw. | | 1 | | | | | | | | | | | 1 | | | Wk. | |
| :arderi, H. Woodw. | | | | | | | | | | | | | 1 | | | D. | |
| elegans, Oppel | | | | | | | | 7 | | 9 | | | | m | u | S. | |
| evis, Blake | | | | 3 | 4 | | | | | | | | 1 | | | Wk. Y. | |
| antiquus, Brod. | | | | | | | | | | 9 | | | 1 | | ? | D. S. ? - | *Coleia.* |
| arrovensis, M'Coy | | 1 | | | | | | | | | | | 1 | | | Wk. Le. | |
| rodiei, H. Woodw. | | | | | | | | | | | | | 1 | | | D. | |
| assichelis, H. Woodw. | | | | | | | | | | | | | 1 | | | D. - - | ? *Archæastacus Willemoesi*, S. Bate. |
| Moorei, H. Woodw. | | | | | | | | | | 9 | | | | | u | S. | |
| ilmcotensis, H. Woodw. | | 1 | | | | | | | | | | | 1 | | | Wk. | |
| ea Heeri, Oppel | | | | | | | | | | | | | 1 | | | D. | |
| asina, von Meyer | | | | | | | | | | | | | 1 | | | D. | |
| estrata, Phil. | | | 2 | | | | | | | | | | 1 | | | S. | |
| omesi, H. Woodw. | | | | | | | | | | | | | 1 | | | Wk. | |
| a Frischmanni, Oppel | | | | | | | | | | ? | | | | m | ? | S. | |
| ia ? polita, Oppel | | | | | | | | | | | 10 | | | | u | Nn. | |
| rina longipes, Münst. | | | | | | | | | | 9 | | | 1 | m | u | D. S. | |
| gmaea, Münst. | | | | | | | | | | 9 | | | | | u | S. | |
| s latipes, Oppel | | | | | | | | | | 9 | | | | m | u | S. | |

| SPECIES. | Rhætic Beds. | Lower. | | | | | Middle. | | Upper. | | | | Lower Lias. | Middle Lias. | Upper Lias. | LOCALITIES. | REMARKS. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Am. margaritatus. | Am. spinatus. | Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | | | | | |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| CRUSTACEA—*cont.* | | | | | | | | | | | | | | | | | |
| *Macroura*—cont. | | | | | | | | | | | | | | | | | |
| Penæus Sharpi, H. Woodw. | | | | | | | | | | | 10 | | | | u | Nn. | |
| Præatya scabrosa, H. Woodw. | | 1 | | | | | | | | | | | 1 | | | S. Le. | |
| Pseudoglyphea grandis, von Meyer. | | | 2 | | | | | | | | | | 1 | | | S. | |
| Scapheus ancylochelis, H. Woodw. | | | 2 | | | | | | | | | | 1 | | | D. | |
| *Cirripedia.* | | | | | | | | | | | | | | | | | |
| Pollicipes rhomboidalis, Moore. | | | 2 | | | | | | | | | | 1 | | | S. Gl. | |
| *Ostracoda.* | | | | | | | | | | | | | | | | | |
| Bairdia dispersa, Blake - | | | | 3 | 4 | | | | 8 | | | | 1 | | u | Wk. Y. | |
| —— liassica, Brodie - | × | 1 | 2 | | 4 | 5 | 6 | | 8 | 9 | | | 1 | | u | O.Wk. Nn.Y. | *Cythere.* |
| —— redcarensis, Blake - | | | 2 | | 4 | | | | | | | | 1 | | | Wk. Y. | |
| Cythere juglandica, Jones - | | | | | | | | | | | 10 | | | | u | × Nn. | |
| —— Moorei, Jones - | | 1 | | | | | | | 8 | 9 | 10 | | 1 | | u | O. Nn. Y. | |
| —— mundula, Jones - | | | 2 | | | | | | | | | | 1 | | | S. - - | *Normania.* |
| —— translucens, Blake - | | | 2 | | 4 | | | | | 9 | | | 1 | | u | Wk. Nn. Y. | |
| —— triangulata, Blake - | | | | | 4 | | | | | | | | 1 | | | Wk. Y. | |
| Cytherella aspera, Jones - | | | 2 | | | | | | | | | | 1 | | | S. | |
| —— crepidula, Blake - | | | | | | 5 | 6 | | | | | | 1 | m | | Nn. Y. | |
| Moorea obesa, Jones - | | | | | | | | | | | | | | | | S. Lias ? - | *M. obtusa* (misp |
| —— tenuis, Jones - - | | | | | | | | | | | | | | | | S. Lias ? | |
| Polycope cerasia, Blake - | | | 2 | | 4 | | 6 | | | | | | 1 | | | Wk. Nn. Y. | |
| INSECTA. | | | | | | | | | | | | | | | | | |
| *Orthoptera.* | | | | | | | | | | | | | | | | | |
| Akicera Frauenfeldi, Gieb. | | 1 | | | | | | | | | | | 1 | | | - - - | Lias. |
| —— Heeri, Gieb. - - | | 1 | | | | | | | | | | | 1 | | | - - - | *Blatta* (Brodie) |
| Diastatomma liasina, Strickl. | | 1 | | | | | | | | | | | 1 | | | G. Wk. Wo. | *Æschna.* *Li* *Hopei*, Brod. |
| Gryllus Bucklandi, Brod. - | | 1 | | | | | | | | | | | 1 | | | Wk. | |
| Heterophlebia Buckmani, Brod. | | | | | | | | | | 9 | | | | | u | G. - - | *Agrion*; *Li* *dislocata*, Brod |
| —— Westwoodi, Hagen - | | | | | | | | | | | | | 1 | | | G. - - | *Libellula.* |
| Libellula Brodiei, Buckm. | | | | | | | | | | 9 | | | | | u | G. - - | *Æschna.* |
| —— decapitata, Hagen - | | | | | | | | | | 9 | | | | | u | G. | |
| Locusta ? - | | 1 | | | | | | | | | | | 1 | | | G. | |

| Species. | Rhætic Beds. | Lower. Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Middle. Am. margaritatus. | Am. spinatus. | Upper. Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| SECTA—*cont.* | | | | | | | | | | | | | | | | | |
| *eodictyoptera.* | | | | | | | | | | | | | | | | | |
| ttina Butleri, Scud. | | | | | | | | | | | | | | | | Lias. | |
| incompleta, Gieb. | | 1 | | | | | | | | | | | 1 | | | G. | |
| na, Gieb. - - | | 1 | | | | | | | | | | | 1 | | | G. | |
| :tina Bensoni, Scud. | | | | | | | | | | 9 | | | | | u | G. | |
| tei, Scud. - - | | | | | | | | | | 9 | | | | | u | G. | |
| tiei, Scud. - - | | 1 | | | | | | | | | | | 1 | | | Wk. | |
| lattina Curtisi, | | | | | | | | | | 9 | | | | | u | G. | |
| rmixta, Scud. - | | | | | | | | | | 9 | | | | | u | G. | |
| *Rhynchota.* | | | | | | | | | | | | | | | | | |
| ium liasinum, Gieb. | | 1 | | | | | | | | | | | 1 | | | G. | |
| [urchisoni, Brod. - | | 1 | | | | | | | | | | | 1 | | | G. | |
| - - - | | 1 | | | | | | | | | | | 1 | | | G. | |
| rus Zucholdi, Gieb. | | 1 | | | | | | | | | | | 1 | | | G. | |
| - - - | | 1 | | | | | | | | | | | 1 | | | G. | |
| *Diptera.* | | | | | | | | | | | | | | | | | |
| notus, Brod. - | | 1 | | | | | | | | | | | 1 | | | G. | |
| - - - | | 1 | | | | | | | | | | | 1 | | | G. | |
| *Neuroptera.* | | | | | | | | | | | | | | | | | |
| lites minor, Blake | | 1 | | | | | | | | | | | 1 | | | G. Y. | |
| leyrichi, Gieb. - | | | | | | | | | | 9 | | | | | u | G. | |
| leta, Gieb. - | | 1 | | | | | | | | | | | 1 | | | - - - | Lias. |
| ilis, Gieb. - - | | 1 | | | | | | | | | | | 1 | | | G. - - | *Chauliodes.* |
| lis, Gieb. - - | | | | | | | | | | | | | | | | - - - | Lias. |
| ius Higginsi, Brod. | | 1 | | | | | | | | | | | 1 | | | G. (Aust.). | |
| lebia communis, . | | 1 | | | | | | | | | | | 1 | | | G. Wo. Wk. | |
| ata, Gieb. - - | | 1 | | | | | | | | | | | 1 | | | G. (Aust.) - | *Hemerobius.* |
| rmedia, Gieb. - | | 1 | | | | | | | | | | | 1 | | | Wo. - - | *Chauliodes.* |
| , Gieb. - - | | 1 | | | | | | | | | | | 1 | | | G. - - | *Chauliodes.* |
| na, Gieb. - - | | 1 | | | | | | | | | | | 1 | | | G. (Aust.). | |
| gissima, Gieb. - | | | | | | | | | | | | | | | | - - - | Lias. |
| llela, Gieb. - | | 1 | | | | | | | | | | | 1 | | | Wo. - - | *Chauliodes.* |
| ilis, Gieb. - - | | 1 | | | | | | | | | | | 1 | | | Wk. - | *Chauliodes.* |
| mes Ellisii, H. r. | | 1 | | | | | | | | | | | 1 | | | Le. | |
| asina, Gieb. - | | 1 | | | | | | | | | | | 1 | | | Wo. - - | *Ephemera* (Brodie). |

| Species. | Rhætic Beds. | Lower. Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Middle. Am. margaritatus. | Am. spinatus. | Upper. Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 3 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| Insecta—*cont.* | | | | | | | | | | | | | | | | | |
| *Coleoptera.* | | | | | | | | | | | | | | | | | |
| Ancylochira liasina, Gieb. - | | 1 | | | | | | | | | | | 1 | | | Wo. | |
| Buprestites bractoides, Blake. | | 1 | | | | | | | | 9 | | | 1 | | | G. Y. | |
| —— sp. - - - | | 1 | | | | | | | | | | | 1 | | | Le. | |
| Chrysomela Andraei, Gieb. | | 1 | | | | | | | | | | | 1 | | | G. | |
| — liasina, Gieb. - - | | 1 | | | | | | | | | | | 1 | | | G. | |
| Elater angulatus, Gieb. - | | 1 | | | | | | | | | | | 1 | | | G. | |
| — Neptuni, Gieb. - | | | | | | | | | | | | | | | | - - - | Lias. |
| — Redtenbacheri, Gieb. - | | | | | | | | | | 9 | | | | | u | G. | |
| — socius, Gieb. - - | | 1 | | | | | | | | | | | 1 | | | G. | |
| — vanus, Gieb. - - | | 1 | | | | | | | | | | | 1 | | | G. | |
| — vetustus, Brod. - | | 1 | | | | | | | | | | | 1 | | | G. | |
| Gyrinus dubius, Gieb. - | | | | | | | | | | | | | | | | - - - | Lias. |
| — natans, Brod. - - | | 1 | | | | | | | | | | | 1 | | | G. | |
| Harpalus Heeri, Gieb. - | | 1 | | | | | | | | | | | 1 | | | G. | |
| — liasinus, Gieb. - - | | 1 | | | | | | | | | | | 1 | | | G. (Aust.). | |
| — Schlotheimi, Gieb. - | | 1 | | | | | | | | | | | 1 | | | G. | |
| Laccophilus aquaticus, Brod. | | 1 | | | | | | | | | | | 1 | | | G. | |
| Melolontha - - - | | 1 | | | | | | | | | | | 1 | | | Wo. | |
| Telephorus Haueri, Gieb. - | | 1 | | | | | | | | | | | 1 | | | G. | |
| Tettigonia - - - | | 1 | | | | | | | | | | | 1 | | | G. | |
| Trogulus - - - | | 1 | | | | | | | | | | | 1 | | | G. | |
| Annelida. | | | | | | | | | | | | | | | | | |
| Ditrupa capitata, Phil. - | | | 2 | | 4 | | | 7 | | | | | 1 | m | | S. Le. Y. - | *Serpula, Ditrypa* |
| — circinata, Tate - - | | | | 3 | 4 | 5 | 6 | 7 | 8 | | | | 1 | m | u | Wk. O. Nn. Y. | |
| — etalensis, Piette - | | | | | 4 | | | 7 | 8 | | | | 1 | m | u | S. to Le. - | *S. strangulata,* (Moore). |
| — globiceps, Quenst. - | | | 2 | | | | | | | | | | 1 | | | Wk. Y. | |
| — quinquesulcata, Münst. | | | 2 | 3 | 4 | 5 | 6 | 7 | | | | | 1 | m | | G. Wk. Wo. Le. Y. | *S. subpentagona* |
| Galeolaria socialis, Goldf. - | | | 2 | | 4 | | | 7 | | | | | 1 | m | | × S. Wk. Y. - | *Serpula.* |
| Serpula deplexa, Bean - | | | 2 | | 4 | | | | | | 10 | 11 | 1 | | u | × Nn. Y. - | *S. flaccida,* Gold |
| — gordialis, Goldf. - | | | | | | | | | | 9 | | | | | u | O. | |
| — limax, Goldf. - - | | | 2 | | 4 | | 6 | 7 | | 9 | | | 1 | m | u | × G. O. Wk. Y. | |

| Species. | Rhætic Beds. | Lower. Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Middle. Am. margaritatus. | Am. spinatus. | Upper. Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| ANNELIDA—*cont.* | | | | | | | | | | | | | | | | | |
| Serpula lumbricalis, Schl. | | | | | | | | | 8 | 9 | | | | | u | O. | |
| — plicatilis, Goldf. - | | | 2 | | 4 | | | | | | | | 1 | m | u | × D. G. Wk. Li. Y. | |
| — quinquecristata, Münst. | | | | | | | | | 8 | | | | | | u | O. Nn. | |
| — segmentata, Dum. - | | | | | | | | | | 9 | | | | | u | O. | |
| — subpentagona, Tate - | | | | 3 | 4 | | 6 | | | | | | 1 | m | | G. | |
| — tetragona, Desl. - | | | | | | | | 7 | 8 | | | | | m | u | × O. Nn. Le. | |
| — tricristata, Goldf. - | | | | | 4 | | | 7 | | 9 | | | 1 | m | u | G. O. Wk. Le. | |
| — triedra, Quenst. - | | | | | | | | | 8 | | | | | | u | O. | |
| ECHINODERMATA. | | | | | | | | | | | | | | | | | |
| *Crinoidea.* | | | | | | | | | | | | | | | | | |
| Cotylederma - - | | | | | | | 6 | | | | | | | m | | D. - - | *Plicatocrinus*, Moore. |
| Extracrinus briareus, Mill. | | | 2 | 3 | | | | | | | | | 1 | | | D. G. Le. Li. Y. | *E. fossilis*, Blum. |
| — subangularis, Mill. - | | | 2 | | | 5 | 6 | 7 | | | | | 1 | | | D. G. Wk. Y. | |
| Millericrinus Hausmanni, Roem. | | | | | 4 | | | | 8 | 9 | | | 1 | m | u | O. Wk. Nn. | |
| Pentacrinus basaltiformis, Mill. | | | 2 | 3 | 4 | 5 | | 7 | | | | | 1 | m | | D. S. G. Wk. Y. | |
| — Goldfussi, M'Coy. - | | | | | | | | 7 | | | | | | m | | G. | |
| — gracilis, Charlesw. - | | | | | | | 6 | 7 | | | | | | m | | G. Y. | |
| — Johnstoni, Aust. - | | | | | | | 6 | | | | | | | m | | D. | |
| — jurensis, Quenst. - | | | | | | | | | 8 | 9 | 10 | | | | u | × O. Nn. Le. | |
| — lævis, Mill. - - | | | | | | | | 7 | | | | | | m | | Le. | |
| — Milleri, Aust. - - | | | | | 4 | 5 | | | | | | | 1 | | | × Wk. Y. | |
| — psilonoti, Quenst. - | | 1 | 2 | | | | | | | | | | 1 | | | Le. Y. | |
| — robustus, Wright - | | | | | | 5 | | | | | | | 1 | | | G. Le. | |
| — scalaris, Goldf. - | | | | 3 | 4 | 5 | | | | | | | 1 | | | S. to Y. - | ? = *P. punctiferus*, Quenst. |
| — tuberculatus, Mill. - | | | 2 | 3 | | | | | | | | | 1 | | | D. S. G. Gl. Y. | |
| *Echinoidea.* | | | | | | | | | | | | | | | | | |
| Acrosalenia banburiensis, Wright. | | | | | | | | | 8 | | | | | | | O. Nn. | |
| — minuta, Buckm. - | | | | 3 | | | | | | | | | 1 | | | G. Wk. | |
| — parva, Wright - - | | | | 3 | | | | | | | | | 1 | | | Wk. | |
| Cidaris amalthei, Quenst. - | | | | | | | | 7 | | | | | | m | | O. Y. | |
| — Dumortieri, Wright - | | | | | | | | | | 9 | | | | | u | O. | |
| — Edwardsi, Wright - | | 1 | 2 | | 4 | 5 | 6 | 7 | | | | | 1 | m | | D. to Y. | |
| — ilminsterensis, Wright | | | | | | | | | | 9 | | | | | u | S. | |

| Species. | Rhætic Beds. | Lower. Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Middle. Am. margaritatus. | Am. spinatus. | Upper. Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| Echinodermata—*cont.* | | | | | | | | | | | | | | | | | |
| *Echinoidea*—cont. | | | | | | | | | | | | | | | | | |
| Diplocidaris Desori, Wright | | | | | | | | | 8 | 9 | | | | | u | ×. S. Nn. | |
| Eodiadema granulata, Dunc. | | | | | | | | 7 | | | | | | m | | Le. | |
| Hemipedina Bechei, Brod. | | 1 | | | | | | | | | | | 1 | | | D. | |
| —— Bowerbanki, Wright - | | 1 | | | | 5 | | | | | | | 1 | | | D. G. | |
| —— Etheridgei, Wright - | | | | | | | | | | 9 | | | | | u | S. G. | |
| —— Jardini, Wright - | | | | | | 5 | | 7 | | 9 | | | 1 | m | u | S. G. | |
| —— Tomesi, Wright - | | 1 | 2 | | | | | | | | | | 1 | | | G. Wk. Le. Y. | |
| Pseudodiadema lobatum, Wright. | | 1 | | | | | | | | | | | 1 | | | D. | |
| —— Moorei, Wright - | | | | | | | | | | 9 | | | | | u | S. G. | |
| Rhabdocidaris moraldina, Cott. | | | | | | 5 | | 7 | | | | | 1 | m | | S. G. | |
| *Ophiuroidea.* | | | | | | | | | | | | | | | | | |
| Acroura Brodiei, Wright - | | | | | | 5 | | | | | | | 1 | | | G. | |
| Ophioderma Egertoni, Broderip. | | | | | | | 6 | | | | | | | m | | D. S. | |
| —— Gaveyi, Wright - | | | | | 4 | 5 | | | | | | | 1 | | | G. Wk. Y. | |
| —— Milleri, Phil. - - | | | | | | 5 | 6 | | | | | | 1 | m | | G. Y. | |
| —— tenuibrachiata, Forbes | | | | | | | 6 | | | | | | | m | | D. | |
| Ophiolepis Ramsayi, Wright. | | | 2 | | | | | | | | | | 1 | | | G. | |
| *Asteroidea.* | | | | | | | | | | | | | | | | | |
| Luidia Murchisoni, Williamson. | | | | | | 5 | | | | | | | 1 | | | G. Y. | |
| Plumaster ophiuroides, Wright. | | | 2 | | | 5 | | | | | | | 1 | | | Li. Y. | |
| Tropidaster pectinatus, Forbes. | | | | | | 5 | | | | | | | 1 | | | S. G. Y. | |
| Uraster Gaveyi, Forbes - | | | | | | 5 | | | | | | | 1 | | | G. | |
| *Holothuroidea.* | | | | | | | | | | | | | | | | | |
| Chirodota sp. - - | | 1 | 2 | | | | | | | | | | 1 | m | u | S. Nn. Y. | |
| Actinozoa. | | | | | | | | | | | | | | | | | |
| Astrocoenia costata, Dunc. - | | | 2 | | | | | | | | | | 1 | | | Gl. - - | *Stylastraea sinemuriensis*, De Fro |
| —— dendroidea, Dunc. - | | | 2 | | | | | | | | | | 1 | | | Gl. - - | *Stylastraea.* |
| —— favoidea, Dunc. - | | | 2 | | | | | | | | | | 1 | | | Gl. | |

| Species. | Rhætic Beds. | Lower. | | | | | Middle. | | Upper. | | | | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Am. margaritatus. | Am. spinatus. | Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | | | | | |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| Actinozoa—*cont.* | | | | | | | | | | | | | | | | | |
| Astrocœnia gibbosa, Dunc. | | 1 | 2 | | | | | | | | | | 1 | | | Gl. - - | Styloseris. |
| —— insignis, Dunc. - | | | 2 | | | | | | | | | | 1 | | | Gl. - - | *Stylastræa.* |
| —— minuta, Dunc. - - | | | 2 | | | | | | | | | | 1 | | | Gl. - - | *Do.* |
| —— Oppeli, Laube - - | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— parasitica, Dunc. - | | | 2 | | | | | | | | | | 1 | | | Gl. - - | *Stylastræa.* |
| —— pedunculata, Dunc. - | | | 2 | | | | | | | | | | 1 | | | Gl. - - | *Do.* |
| —— plana, Dunc. - - | | | 2 | | | | | | | | | | 1 | | | Gl. - - | *Do.* |
| —— reptans, Dunc. - | | 1 | 2 | | | | | | | | | | 1 | | | Gl. - - | *Do.* |
| —— sinemuriensis, d'Orb. - | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— spinigera, Dunc. - | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— superba, Dunc. - | | | 2 | | | | | | | | | | 1 | | | Gl. - - | *Stylastræa Martini,* De From. |
| Calamophyllia cassiana, Laube. | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| Cladophyllia subdichotoma, Laube. | | | 2 | | | | | | | | | | 1 | | | Gl. - - | *Montlivaltia pedunculata,* Dunc. pars. |
| —— sublævis, Laube - | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| Cyathocœnia costata, Dunc. | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— decipiens, Laube - | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— dendroidea, Dunc. - | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— globosa, Dunc. - - | | 1 | | | | | | | | | | | 1 | | | S. | |
| —— incrustans, Dunc. - | | 1 | 2 | | | | | | | | | | 1 | | | Gl. | |
| Cyathophyllum? novum, Edw. & Haime. | | | 2 | | | | | | | | | | 1 | | | S. | |
| Cyclolites cupuliformis, Tomes. | | | | | | | | 7 | | | | | | m | | O. | |
| Elysastræa Fischeri, Laube | | 1 | 2 | | | | | | | | | | 1 | | | Gl. - - | *E. Moorei,* Dunc. |
| Heterastræa bintonensis, Tomes. | | | 2 | | | | | | | | | | 1 | | | G. Wk. | |
| —— endothecata, Dunc. - | | | 2 | | | | | | | | | | 1 | | | D. Wo. - | *Isastræa.* |
| —— Etheridgei, Tomes - | | | 2 | | | | | | | | | | 1 | | | D. | |
| —— eveshami, Dunc. - | | | 2 | | | | | | | | | | 1 | | | Wo. Wk. - | *Isastræa.* |
| —— excavata, De From. - | | | 2 | | | | | | | | | | 1 | | | Gl. Y. - | *Do.* |
| —— Fromenteli, Terq. & Piette. | | | 2 | | | | | | | | | | 1 | | | Wk. Li. - | *Do.* |
| —— Haimei, Wright - | | 1 | 2 | | | | | | | | | | 1 | | | S. Wo. - | *Do.* |
| —— insignis, Dunc. - | | | 2 | | | | | | | | | | 1 | | | D. - - | *Do.* |
| —— latimæandroidea, Dunc. | | 1 | | | | | | | | | | | 1 | | | S. - - | *Do.* |
| —— Murchisoni, Wright - | | | 2 | | | | | | | | | | 1 | | | Wo. - - | *Do.* |

| Species. | Rhætic Beds. | Lower. | | | | | Middle. | | Upper. | | | | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Am. margaritatus. | Am. spinatus. | Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | | | | | |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| Actinozoa—*cont.* | | | | | | | | | | | | | | | | | |
| Heterastræa regularis, Tomes. | | | 2 | | | | | | | | | | 1 | | | Wo. | |
| —— Stricklandi, Dunc. - | | | 2 | | | | | | | | | | 1 | | | Wo. - - | *Isastræa.* |
| —— Tomesi, Dunc. - - | | | 2 | | | | | | | | | | 1 | | | G. Wo. Wk. | *Do.* |
| Isastræa globosa, Dunc. - | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— Gümbeli, Laube - | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— sinemuriensis, De From. | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— see also Heterastræa. | | | | | | | | | | | | | | | | | |
| Latimæandra denticulata, Dunc. | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| Lepidophyllia hebridensis, Dunc. | | | 2 | | | | | | | | | | 1 | | | Le. | |
| —— Stricklandi, Dunc. - | | | 2 | | | | | | | | | | 1 | | | Wo. | |
| Microsolena - - - | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| Montlivaltia brevis, Dunc. | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— Brodiei, Dunc. - - | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— foliacea, Tomes. - | | | | | | | 6 | | | | | | | m | | D. | |
| —— Guettardi, Blainv. - | | | 2 | | | | | | | | | | 1 | | | Le. Li. Y. | |
| —— Haimei, Chap. & Dew | | 1 | 2 | | | | | | | | | | 1 | | | Li. Y. | |
| —— mucronata, Dunc. - | | | | 3 | 4 | | | | | | | | 1 | | | S. G. Wk. Le. | |
| —— Murchisonæ, Dunc. - | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— nummiformis, Dunc. - | | | | | 4 | | | | | | | | 1 | | | Wk. | |
| —— papillata, Dunc. - | | | 2 | | | | | | | | | | 1 | | | Li. | |
| —— papyracea, Tomes - | | | | | 4 | | | | | | | | 1 | | | Wk. | |
| —— parasitica, Dunc. - | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— patula, Dunc. - - | | | 2 | | | | | | | | | | 1 | | | Wk. | |
| —— pedunculata, Dunc. - | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— perlonga, Laube - | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— polymorpha, Terq. & Piette. | | | 2 | | | | | | | | | | 1 | | | Gl. Y. - | *Thecosmilia major,* de Ferry. |
| —— radiata Dunc. - - | | | | 3 | 4 | | | | | | | | 1 | | | G. Wk. | |
| —— rugosa, Wright - | | | 2 | 3 | 4 | | | | | | | | 1 | | | G. Wo. Wk. | *Thecocyathus.* |
| —— ruperti, Dunc. - - | | | 2 | | | | | | | | | | 1 | | | G. Wk. | |
| —— simplex, Dunc. - | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— Victoriæ, Dunc. - | | | | | | 5 | | | | | | | 1 | | | D. G. O. | |
| —— Walliæ, Dunc. - | | | 2 | | | | | | | | | | 1 | | | Gl. | |

| Species. | Rhaetic Beds. | Lower. | | | | | Middle. | | Upper. | | | | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Am. margaritatus. | Am. spinatus. | Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | | | | | |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| Actinozoa—*cont.* | | | | | | | | | | | | | | | | | |
| Montlivaltia, see also Cladophyllia. | | | | | | | | | | | | | | | | | |
| Rhabdophyllia recondita, Laube. | | 1 | 2 | | | | | | | | | | | | | Gl. | |
| *Septastræa*, see Heterastræa. | | | | | | | | | | | | | | | | | |
| Stylastræa dendroidea, Dunc. | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— gibbosa, Dunc. - - | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— insignis, Dunc. - | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— Martini, De From. - | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— minuta, Dunc. - - | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— parasitica, Dunc. - | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— pedunculata - - | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— plana, Dunc. - - | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— reptans, Dunc. - - | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— sinemuriensis, De From. | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— see also Astrocœnia. | | | | | | | | | | | | | | | | | |
| Thamnastræa Etheridgei, Tomes. | | | | | | | | 7 | | | | | | m | | O. Nn. | *Synastræa.* |
| —— Walfordi, Tomes - | | | | | | | | 7 | | | | | | m | | O. Nn. - | |
| Thecocyathus Moorei, Edw. & Haime. | | | | | | | | | | | | | 1 | | u | S. O. | |
| —— tuberculatus, Tomes - | | | | | | | | | 8 | 9 | | | | | u | G. O. Nn. - | *Montlivaltia.* |
| —— sp. - - - | | | | | | | | 7 | | | | | | m | | Le. | |
| —— see also Montlivaltia. | | | | | | | | | | | | | | | | | |
| Thecosmilia affinis, Dunc. - | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— Brodiei, Dunc. - | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— dentata, Dunc. - | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— Duncani, Tomes - | | | 2 | | | | | | | | | | 1 | | | Gl. - - | *T. irregularis*, Dunc. |
| —— Martini, De From. - | | | 2 | | | | | | | | | | | | | G. Gl. | |
| —— Michelini, Terq. & Piette. | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— mirabilis, Dunc. - | | 1 | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— plana, Dunc. - - | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— rugosa, Laube - - | × | 1 | 2 | | 4 | | | | | | | | 1 | | | G. Gl. | |
| —— serialis, Dunc. - - | | | 2 | | | | | | | | | | 1 | | | Gl. | |
| —— suttonensis, Dunc. - | | 1 | 2 | | | | | | | | | | 1 | | | Gl. | |

| Species. | Rhætic Beds. | Lower: Am. planorbis. | Lower: Am. Bucklandi. | Lower: Am. oxynotus. | Lower: Am. Jamesoni. | Lower: Am. capricornus. | Middle: Am. margaritatus. | Middle: Am. spinatus. | Upper: Am. annulatus. | Upper: Am. serpentinus. | Upper: Am. communis. | Upper: Am. jurensis. | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| ACTINOZOA—*cont.* | | | | | | | | | | | | | | | | | |
| Thecosmilia Terquemi, Dunc. | | 1 | 2 | | | | | | | | | | l | | | Gl. Wk. | |
| —— see also Montlivaltia. | | | | | | | | | | | | | | | | | |
| Tricycloseris Anningi, Tomes. | | | | | | | 6 | | | | | | | m | | D. | |
| Trochocyathus primus, Edw. & Haime. | | | | | | | | | | | | | | | u | S. | |
| —— sp. - - - | | | | | | | | | 8 | | | | | | u | G. | |
| SPONGIDA. | | | | | | | | | | | | | | | | | |
| Cupulospongia - - | | | | | | | | 7 | | | | | | m | | S. | |
| Grantia antiqua, Moore - | | | 2 | | | | | | | | | | l | | | S. Gl. | |
| Leucandra Walfordi, Hinde | | | | | | | | 7 | | | | | | m | | Nn. | |
| Neuropfungia mammillata, De From. | | | 2 | | | | | | | | | | | | | S. | |
| Platychonia Brodiei, Sollas | | | | | | | | 7 | | | | | | m | | S. | |
| FORAMINIFERA. | | | | | | | | | | | | | | | | | |
| Cornuspira infima, Strickl. | | 1 | 2 | 3 | | | | | 8 | | 10 | | l | | u | G. Le. Nn. Y. | *Spirillina, Trochammina.* |
| Cristellaria acutauricularis, Fichtel & Moll. | | | | | | | 6 | 7 | | 9 | 10 | | | m | u | S. Nn. | |
| —— antiquata, d'Orb. - | | | | | | | | | | 9 | | | | | u | O. | |
| —— bacularis, Terq. - | | | | | | | 6 | | | | | | | m | | Nn. | |
| —— Bronni, Roem. - | | 1 | 2 | 3 | | 5 | 6 | | 8 | 9 | | | l | | u | S. O. Nn. Y. | *Planularia, Vaginulina.* |
| —— costata, d'Orb. - | | | 2 | | | | 6 | | | 9 | | | l | | u | S. Nn. | |
| —— crepidula, Fichtel & Moll. | | 1 | 2 | | | 5 | 6 | | 8 | 9 | | | l | | u | ×S. O. Nn. Y. | |
| —— cultrata, Mont. - | | | 2 | | 4 | | | 7 | | 9 | 10 | | l | m | u | × S. O. Nn. | |
| —— desperdita, Terq. - | | | | | | | 6 | | | | | | | m | | Nn. | |
| —— gibba, d'Orb. - - | | | | | | | 6 | | | | | | | m | | Nn. | |
| —— gladius, Philippi - | | | | | | | 6 | | | | | | | m | | Nn. | |
| —— opercula, Cr. & Sh. - | | | | | | | | | | | 10 | | | | u | Nn. | |
| —— pauperata, Jones & Parker. | | 1 | 2 | | | | | 7 | | 9 | | | l | m | u | S. O. Nn. Y. | *Planularia.* |
| —— protracta, Born. - | | | | | | | 6 | | | | 10 | | | m | u | Nn. | |
| —— recta, d'Orb. - - | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | 9 | 10 | | l | m | u | S. O. Wk. Nn. Y. | *Marginulina ensis* Reuss (of Brady) *C. rhomboidea*, Czjzek. |
| —— rotulata, Lam. - | | 1 | 2 | 3 | 4 | 3 | 6 | | | 9 | 10 | | l | m | u | × S. to Y. - | *C. rustica*, Terq. |
| —— varians, Born. - | | 1 | 2 | 3 | | 5 | 6 | | 8 | 9 | 10 | | l | m | u | O. Nn. Y. | ? = *C. Bronni.* |
| —— see also Planularia. | | | | | | | | | | | | | | | | | |

| Species. | Rhætic Beds. | Lower. | | | | | Middle. | | Lower. | | | | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Am. margaritatus. | Am. spinatus. | Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | | | | | |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| Foraminifera—*cont.* | | | | | | | | | | | | | | | | | |
| Dentalina aculeata, d'Orb. | | | | | | | | | | | | | | | u | S. | |
| —— brevis, d'Orb. - | | 1 | 2 | | 4 | | | | | | 10 | | 1 | | u | Wk. Nn. Y. | *D. perlucida*, Terq. |
| —— burgundiæ, Terq. - | | | | 3 | | | | | 8 | 9 | | | 1 | | u | O. Y. | |
| —— communis, d'Orb. - | | 1 | 2 | | 4 | 5 | 6 | 7 | | 9 | 10 | | 1 | m | u | S. O. Nn. Wk. Y. | *D. torta*, Terq. *Nodosaria*. |
| —— glandulosa, Terq. - | | 1 | 2 | | | | | | | 9 | | | 1 | | u | S. O. Y. - | *D. filiformis*, d'Orb. (of Brady). |
| —— guttifera, d'Orb. - | | | 2 | | | | | | | 9 | | | | | u | Nn. | |
| —— interrupta, d'Orb. - | | | 2 | | | | | | | | | | 1 | | | S. | |
| —— Lilli, Reuss - - | | | | | | | | | | 9 | | | | | u | Nn. | |
| —— mucronata, Neug. - | | | | | | | 6 | | | | | | | m | | Nn. | |
| —— multicostata, Terq. - | | | | | | | 6 | | | | | | | m | | Nn. | |
| —— nodosa, d'Orb. - - | | 1 | | | 4 | | | | | | | | 1 | | | Wk. Y. | |
| —— nummulina, Gümb. - | | | | | | 5 | | | 8 | 9 | | | 1 | | u | O. Y. | |
| —— obliqua, Linn. - - | | | 2 | | 4 | | | 7 | | 9 | | | 1 | m | u | S. Nn. | |
| —— obliquestriata, Reuss - | | | 2 | | 4 | 5 | | | | 9 | | | 1 | | u | S. O. Wk. Y. | |
| —— ornata, Terq. - - | | | | | | | | | | 9 | | | | | u | O. | |
| —— ovicula, d'Orb. - - | | | 2 | | | | | | | | | | 1 | | | S. | |
| —— pauperata, d'Orb. - | | 1 | 2 | | 4 | | 6 | 7 | 8 | 9 | 10 | | 1 | m | u | S. to Y. - | *D. irregularis*, Terq. *D. obscura*, Terq. |
| —— plebeia, Reuss - - | | | | | | | | 7 | | 9 | | | | m | u | S. | |
| —— quadrilatera, Terq. - | | | | | 4 | | | | | | | | 1 | | | Wk. | |
| —— striata, Terq. - - | | | | | 4 | | | | | | | | 1 | | | Wk. | |
| —— vetutissima, d'Orb. - | | | | | | | | | | | 10 | | | | u | Nn. | |
| —— see also Marginulina. | | | | | | | | | | | | | | | | | |
| Flabellina rugosa, d'Orb. - | | 1 | 2 | | 4 | | | | | 9 | | | 1 | | u | S. to Y. | |
| Frondicularia angulosa, d'Orb. | | | | | | | | | | | | | | m | | O. | |
| —— complanata, Defr. - | | 1 | 2 | | | | | | | 9 | | | 1 | | u | S. Y. | |
| —— delirata, Crick & Sherb. | | | | | | | 6 | | | | | | | m | | Nn. | |
| —— intumescens, Born. - | | | | | | | 6 | | | | | | | m | | Nn. | |
| —— rugosa, C. & S. - - | | | | | | | 6 | | | | | | | m | | Nn. | |
| —— sulcata, Bornemann - | | 1 | 2 | | 4 | 5 | 6 | 7 | | 9 | | | 1 | m | u | S. to Y. - | *F. striatula*, Reuss (of Brady). |
| —— Terquemi, d'Orb. - | | | 2 | | 4 | 5 | 6 | | | | | | 1 | m | | Wk. Nn. Y. | |
| Glandulina lævigata, d'Orb. | | | | | | | 6 | | | | | | | m | | Nn. | |
| —— see also Nodosaria. | | | | | | | | | | | | | | | | | |
| Involutina liassica, Jones - | | | 2 | | | | | | | | | | 1 | | | S. G. Wo. Y. | *Nummulites*. |

| Species. | Rhætic Beds. | Lower. Am. planorbis. | Lower. Am. Bucklandi. | Lower. Am. oxynotus. | Lower. Am. Jamesoni. | Lower. Am. capricornus. | Middle. Am. margaritatus. | Middle. Am. spinatus. | Upper. Am. annulatus. | Upper. Am. serpentinus. | Upper. Am. communis. | Upper. Am. jurensis. | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| FORAMINIFERA—*cont.* | | | | | | | | | | | | | | | | | |
| Lagena - - - | | | | | 4 | | | | | | | | 1 | | | Wk. | |
| Lingulina carinata, d'Orb. | | | 2 | | | | | 7 | | 9 | | | 1 | m | u | S. | |
| —— tenera, Born. - - | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | | | 1 | m | u | S. to Y. | |
| Lituola cenomana, d'Orb. - | | | | | | | | | | 9 | | | | | u | S. | |
| Marginulina 12-costata, Terq. | | | | | 4 | | | | | | | | 1 | | | Wk. | |
| —— glabra, d'Orb. - - | | | | | | 5 | | 7 | | | 10 | | 1 | m | u | × S. O. Nn. | |
| —— inæquistriata, Terq. - | | | 2 | | | | | 7 | | 9 | | | 1 | m | u | S. Y. - | *Planularia* Bre[...] Roem. (of Brady[...] |
| —— interlineata, Terq. - | | | | | 4 | | | | | | | | 1 | | | Wk. | |
| —— lata, Cornuel - - | | | | | | | | | | 9 | | | | | u | Nn. | |
| —— lituus, d'Orb. - - | | | 2 | | | | | | | | | | 1 | | | S. | |
| —— picta, Terq. - - | | 1 | 2 | 3 | | | | | | 9 | | | 1 | | u | O. Y. - | *Dentalina quadr*[...] *tata*, Terq. |
| —— prima, d'Orb. - - | | | | | | | | | | | 10 | | | | u | Nn. | |
| —— —— var. acuta, Terq. - | | | | | 4 | | | | | | | | 1 | | | Wk. | |
| —— raphanus, Linn. - | | 1 | 2 | | 4 | | 6 | 7 | | 9 | | | 1 | m | u | × S. Nn. Y. | |
| —— see also Cristellaria and Planularia. | | | | | | | | | | | | | | | | | |
| Miliola - - - | | | | 3 | 4 | | | | | | | | 1 | | | Wk. Le. | |
| Nodosaria badenensis, d'Orb. | | | | | | | | | | 9 | | | | | u | O. | |
| —— fascia, Linn. - - | | | 2 | | | | | | | | | | 1 | | | S. | |
| —— hispida, d'Orb. - | | | | | | | | 7 | | 9 | | | | m | u | S. | |
| —— humilis, Roem. - | | | | | | 5 | 6 | 7 | | 9 | | | | m | u | S. Nn. Y. - | *Glandulina.* |
| —— mutabilis, Terq. - | | | | | | | 6 | | | | | | | m | | Nn. | |
| —— nitida, d'Orb. - - | | 1 | | | 4 | 5 | | | | | | | 1 | m | | O. Wk. Y. | |
| —— paucicosta, Roem. - | | 1 | 2 | | | | | 7 | | 9 | | | 1 | m | u | S. Y. - | *Glandulina.* |
| —— radicula, Linn. - | | | 2 | | 4 | | 6 | 7 | | 9 | | | 1 | m | u | S. Wk. Nn. Y. | *Glandulina* co[...] Terq. |
| —— raphanistrum, Linn. - | | 1 | 2 | | 4 | 5 | 6 | | 8 | 9 | | | 1 | m | u | S. to Y. | |
| —— raphanus, Linn. - | | 1 | 2 | | 4 | 5 | 6 | 7 | | 9 | | | 1 | m | u | S. to Y. | |
| —— simoniana, Terq. - | | | | | 4 | | | | | | | | 1 | | | Wk. | |
| —— see also Dentalina. | | | | | | | | | | | | | | | | | |
| Nonionina - - - | | | | | | | | | | | | | 1 | | | Le. | |
| Nubecularia tibia, P. & J. - | | | | | | | | | | 9 | 10 | | | | u | Nn. O. | |
| *Nummulites*, see Involutina. | | | | | | | | | | | | | | | | | |
| Ophthalmidium birmensdorfensis, Kübler & Zwingli. | | | | | | | | | | | | | | | u | O. | |

| Species. | Rhætic Beds. | Lower. | | | | | Middle. | | Upper. | | | | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Am. margaritatus. | Am. spinatus. | Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | | | | | |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| AMINIFERA—*cont.* | | | | | | | | | | | | | | | | | |
| lmidium nubeculari-ormis, Haeusler. | | | | | | | | | | | | | | | u | O. | |
| alfordi, Haeusler - | | | | | | | | | | | | | | | u | O. | |
| ıa universa, d'Orb. - | | | 2 | | 4 | | | | | | | | 1 | | | Wk. Y. | |
| aria cornucopiæ, ?. | | | 2 | | | | | | | 9 | | | 1 | | u | S. | |
| rpula, d'Orb. - | | | | | | | | | | 9 | | | | | u | S. O. - | *Marginulina.* |
| ıga, Cornuel - | | | 2 | | | | | 7 | | 9 | | | 1 | m | u | S. - - | ?=*Cristellaria major*, Born. |
| iculata, Cornuel - | | | | | | | | 7 | | 9 | | | | m | u | × O. Nn. | |
| e also Cristellaria Marginulina. | | | | | | | | | | | | | | | | | |
| rphina compressa, ». | | 1 | | | | | | 7 | | | | | 1 | m | | S. Y. | |
| siformis, Roem. - | | 1 | 2 | | | 5 | 6 | 7 | 8 | 9 | | | 1 | m | u | S. G. Nn. Y. | *P. liassica*, Strickl. |
| tea, Walker & ». | | | | | | | | 7 | | | 10 | | | m | u | S. Nn. | |
| dosaria, Reuss - | | | 2 | | 4 | | | | | | | | 1 | | | Wk. Y. | |
| alina caracolla, Roem. | | | | | | | | | | | 10 | | | | u | Nn. | |
| gans, d'Orb. - | | 1 | 2 | | | | | | 8 | 9 | | | 1 | | u | Nn. Y. | |
| *ina*, see Cornuspira. | | | | | | | | | | | | | | | | | |
| alina infraoolithica, . | | | | | | | | | | 9 | | | | | u | Nn. | |
| aria - - - | | | | 3 | | | | | | | | | 1 | | | Le. | |
| mmina incerta, rb. | | | 2 | | | 5 | 6 | | 8 | | 10 | | 1 | m | u | S. O. Nn. Y. | *Ammodiscus.* |
| e also Cornuspira. | | | | | | | | | | | | | | | | | |
| lina costulata, Reuss. | | | | | | | | | | 9 | | | | | u | Nn. | |
| rdialis, P. & J. - | | | | | 4 | | | | | | | | 1 | | | Wk. | |
| vigata, Roem. - | | | 2 | | | | | 7 | | 9 | | | 1 | m | u | S. | |
| gumen, Linn. - | | | 2 | | | 5 | 6 | 7 | | 9 | | | 1 | m | u | × S. Nn. Y. | |
| riata, d'Orb. - | | | 2 | | | | | | | 9 | 10 | | 1 | | u | S. O. Nn. | |
| rigillata, Reuss. - | | | | | | | | | | 9 | 10 | | | | u | × Nn. - | *Dentalina.* |
| e also Cristellaria. | | | | | | | | | | | | | | | | | |
| ina - - - | | | | | | | | | | | | | | m | | S. | |
| na irregularis, d'Orb. | | | | | | | | | | 9 | 10 | | | | u | S. Nn. | |
| gosa, d'Orb. - - | | | | | | | | | | | | | | | u | S. | |

| Species. | Rhætic Beds. | Lower. Am. planorbis. | Am. Bucklandi. | Am. oxynotus. | Am. Jamesoni. | Am. capricornus. | Middle. Am. margaritatus. | Am. spinatus. | Upper. Am. annulatus. | Am. serpentinus. | Am. communis. | Am. jurensis. | Lower Lias. | Middle Lias. | Upper Lias. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | |
| **PLANTÆ.** | | | | | | | | | | | | | | | | | |
| GYMNOSPERMÆ. | | | | | | | | | | | | | | | | | |
| *Coniferæ.* | | | | | | | | | | | | | | | | | |
| Brachyphyllum solitarium, Phil. | | | | | | | | | | | | | 1 | | | Wk. | |
| Pachyphyllum peregrinum, Sternb. | | | 2 | 3 | | | | | | 9 | | | 1 | | u | D. G. Y. - | *Araucarites*; *Str lites*; *Pinites e gatus*, L. & H.; *pressus latifol* Buckm. |
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| Cycadites concentricus, Rich. | | | | | | | | | | | | | | | | | Lias (British Museu |
| —— rectangularis, Brauns. | | | | | | | | | | | | | 1 | | | D. | |
| Cycadeoidea pygmæa, Lindl. & Hutt. | | | | | | | | | | | | | 1 | | | D. - - | *Zamites*, *Mantellia*. |
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| —— gracilis, Phil. - - | | 1 | | | | | | | | | | | 1 | | | G. | |
| —— obtusus, L. & H. - | | 1 | 2 | | | | | | | | | | | | | × De. D. S. G. Wk. Y. | *Odontopteris ot teris*, Göpp.; *Pa ozamia Bucklan* Brongn.; *P. Bec* Brongn. |
| Ptilozamites Bergeri, Göpp. | | | ? | | | | | | | | | | 1 | | | D. - - | *Ctenopteris cycad* Brongn.; *Cycad teris*. |
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| *Filices.* | | | | | | | | | | | | | | | | | |
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| Lomatopteris jurensis, Kurr. | | 1 | | | | | | | | | | | 1 | | | Wk. | |
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| *Algæ.* | | | | | | | | | | | | | | | | | |
| Chondrites bollensis, Ziet. | | | | | | | | | | 9 | | | | | u | S. O. | |
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